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Soil Survey of Iowa, Report No. 27—Adair County Soils

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SOIL SURVEY OF IOWA

ADAIR COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE AND MECHANIC ARTS

Agronomy Section

Soils

Soil Survey Report No. 27

July, 1922

Ames, Iowa

IOWA AGRICULTURAL EXPERIMENT STATION

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11 Methods for the Bacteriological Examinations of Soils.*
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25 Bacterial Activities and Crop Production.
34 Studies in Sulfofication.
35 Effects of Some Manganese Salts on Ammonification and Nitrification.
36 Influence of Some Humus-Forming Materials of Narrow and of Wide Nitrogen-Carbon Ratio on Bacterial Activities.
39 Carbon Dioxide Production in Soils and Carbon and Nitrogen Changes in Soils Variously Treated.
43 The Effect of Sulfur and Manure on the Availability of Rock Phosphate in Soil.
44 The Effect of Certain Alkali Salts on Ammonification.
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56 The Effect of Seasonal Conditions and Soil Treatment on Bacteria and Molds in the Soil.
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SOIL REPORTS

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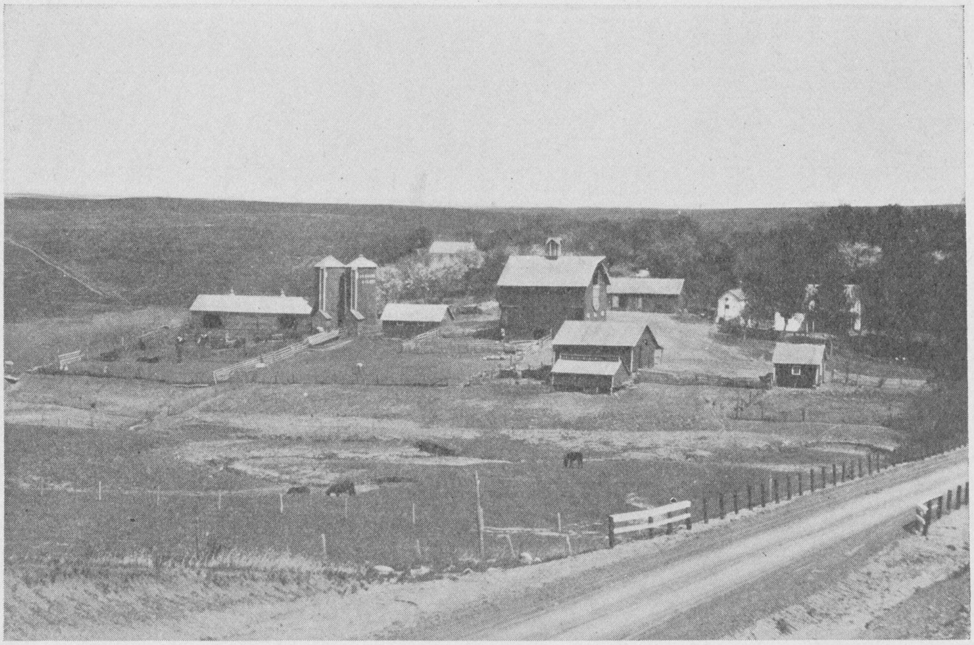
July, 1922 Soil Survey Report No. 27

SOIL SURVEY OF IOWA

Report No. 27—ADAIR COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman. T. H. Benton, and P. C. Wiechmann



A well-equipped farmstead in Adair county.

IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtis, Director
Ames, Iowa

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THE SOILS OF ADAIR COUNTY*

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, T. H. Benton, and P. C. Wiechmann

Adair county is located in southeastern Iowa, in the third tier of counties north of Missouri and the third tier east from the Nebraska line. It lies partly in the Southern Iowa loess soil area and partly in the Missouri loess. The soils of the county are largely loessial in origin, but in the Southern Iowa loess section a large part of the area is covered by a drift soil derived from the underlying drift formation, from which the thin covering of loess has been entirely removed.

The total area of Adair county is 573 square miles, or 366,720 acres. Of this area 349,897 acres or 95.4 percent is in farm land. The total number of farms is 2,132; the average size of the farms is 164 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the utilization of the farm land of the county:

Acreage in general farm crops	213,411
Acreage in pasture	112,340
Acreage in farm buildings, feedlots and public highways	16,204
Acreage in waste land	1,113
Acreage in crops not otherwise listed	222

The type of agriculture practiced in Adair county consists mainly of general farming and includes the raising of livestock and the production of some grains for market. The livestock industry is developing rapidly and includes principally the raising and feeding of beef cattle and hogs and to a less extent the raising of sheep, horses and mules. The crops grown are utilized mainly for feeding, but some of the grain produced, particularly the corn and wheat, is marketed. The livestock industry of the county may probably be considered of major importance, and the general farming practices which have been largely followed in the past are gradually changing to a livestock system.

There is a rather considerable area of waste land in the county, which may be very largely reclaimed thru proper methods of soil treatment. It is quite impossible to make general recommendations for the reclamation of waste land, owing to the fact that the causes of infertility are so variable. Special treatments which are needed for individual soil conditions are suggested in a later section of this report. Where the soil conditions are more or less abnormal, advice may be secured regarding the best method of handling the soil from the Soils Section of the Iowa Agricultural Experiment Station upon request.

The general farm crops grown in Adair county, in the order of their importance, are corn, oats, hay, wheat, barley, potatoes, rye and alfalfa. The average yields and value of these crops are given in table I.

Corn is the most important crop, both in acreage and value. One-third of the total area of the farm land in the county is devoted to this crop and average yields of 43 bushels per acre were secured in 1920. Both the yellow and white dent varieties are grown. Reid's Yellow Dent is the most popular yellow variety and Silvermine, Johnson County White and Boone County White are

*See Soil Survey of Adair County, Iowa, by Clarence Lounsbury of the U. S. Department of Agriculture and T. H. Benton and P. C. Wiechmann of the Iowa Agricultural Experiment Station.

TABLE I. AVERAGE YIELD AND VALUE OF CROPS GROWN IN ADAIR COUNTY, IOWA*

Crop	Acres	Percent of total farm land in the county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	117,700	33.6	43.0	5,061,000	$0.47	$2,378,670
Oats	49,300	14.0	39.0	1,922,700	0.36	682,172
Spring wheat	5,240	1.4	9.0	47,200	1.35	63,720
Winter wheat	4,500	1.2	18.0	81,000	1.41	114,210
Barley	8,280	2.3	27.0	223,560	0.63	141,842
Rye	650	0.1	12.0	7,800	1.17	9,126
Potatoes	781	0.2	79.0	61,699	1.22	75,272
Tame hay	22,050	6.3	1.4	30,870	16.24	501,328
Wild hay	4,770	1.3	2.0	9,540	12.69	121,062
Alfalfa	140	0.04	4.0	140	19.23	2,692
Pasture	112,340	32.1	....	....	....	....

the most commonly grown white varieties. A large part of the corn grown in the county is used on the farms for feeding purposes, but there is some sale of this crop out of the county. Some corn is grown for silage and utilized in this way for stock feeding.

The second crop in acreage and value in the county is oats. The value of this crop is very much less than that of the corn and it is grown on a much smaller total acreage. Average yields of oats amount to 39 bushels per acre. Iowa 103 and 105 are probably the most commonly grown varieties, tho some farmers prefer the Kherson variety. Practically all of the oats grown are utilized for feed on the farm and it is only very seldom that there is any surplus of this crop for sale on the outside markets.

Hay is the third crop of importance, there being a much larger acreage in the tame varieties than in wild hay. The total value of the tame hay and wild hay together is almost the same as the value of the oats grown in the county. Over 6 percent of the area of the county is utilized for hay, timothy and clover mixed being grown most commonly. Rather considerable areas are utilized for timothy alone and a much smaller area is seeded to clover alone. Average yields of tame hay amount to 1.4 tons per acre, while the average yield of the wild prairie grasses amounts to 2 tons per acre. Practically all of the hay produced in the county is fed on the farms.

Some wheat is grown, and the value of this crop is considerable. Both the spring varieties and the winter varieties are produced, the yields of the winter varieties, however, being very much better than those of the spring varieties. The total value of the winter wheat in 1920 was almost twice that of the spring wheat, altho the area was somewhat larger for the latter variety. Wheat is a cash crop and is mainly shipped out to the Chicago, St. Joseph or Kansas City markets.

Barley is a rather important crop, and average yields of 27 bushels per acre are secured. The value of this crop is considerable; in fact, it ranks next to wheat in importance. Some barley is sold, but the major portion of the crop is utilized for feeding purposes.

Rye is grown on a small area and is a relatively unimportant crop. Emmer and buckwheat are crops of minor importance, and there are small acreages

*Iowa Yearbook of Agriculture, 1920.

devoted to millet and alfalfa. The latter crop is becoming more popular as more is learned regarding the methods to be followed in seeding and harvesting. Average yields of this crop amount to 4 tons per acre and it makes a valuable feed. When the soil is put in a satisfactory physical condition and good seed is used, a satisfactory stand of alfalfa should be secured.

Potatoes are grown rather extensively in the county, chiefly to supply the home demand. Average yields of 79 bushels per acre are secured. Some sorghum is grown and utilized both for syrup and for forage. In the year of the survey, a rather large acreage was devoted to sugar beets.

There are no commercial orchards in the county, but practically every farmer maintains an apple orchard and produces enough fruit to supply the home demand, with occasionally a small surplus. The orchards are not generally cared for as well as they should be, and where pruning and spraying are practiced, the yields of apples are very much larger. There are some peach, plum and cherry trees on the farms and various small fruits are grown. These are all utilized to supply the home demand.

THE LIVESTOCK INDUSTRY OF THE COUNTY

The livestock industries of the county include the raising and feeding of cattle, hogs and sheep and the raising of horses and mules. Some dairying is practiced, also. The following figures, taken from the Iowa Yearbook of Agriculture for 1920, show the extent of the livestock industry of the county:

Horses, all ages	13,864
Mules, all ages	1,279
Swine, on farms July 1, 1920	99,796
Swine, on farms Jan. 1, 1921	80,816
Cattle, (cows and heifers, kept for milk)	8,597
Cattle, (other cattle not kept for milk)	35,832
Cattle, (all ages Jan. 1, 1921)	44,429
Sheep, (all ages on farms Jan. 1, 1921)	16,084
Sheep, (shipped in for feeding 1920)	2,906
Sheep, (total pounds of wool clipped)	110,054
Poultry, (total all varieties Jan. 1, 1921)	274,914
Poultry, (number dozen eggs received 1920)	1,054,297

Beef cattle raising and feeding is one of the most important of the livestock industries, most of the cattle being raised in the county, but some feeders are shipped in for finishing. Of the various breeds, the Shorthorns seem to be the most popular. There are also some herds of Hereford or Aberdeen Angus and a few grade Jerseys and Holsteins. Herds range in size from 25 or 30 on the average farm to 100 or more on larger farms.

Dairying is practiced to some extent in the county and most farmers keep some milk cows, chiefly Shorthorns. The value of the dairy products is considerable. Besides supplying the home demand, the products are sold to the creameries and out of the county. There is a creamery at Greenfield and others at Adair and at Menlo in Guthrie county. Much of the butter produced at the Greenfield creamery is shipped to New York.

The raising and fattening of hogs is a general practice in the county and practically every farmer raises some hogs and in many instances the swine industry is the most important. The Poland China breed is the most popular, but the Duroc Jersey and Chester White breeds are also favored. Many of the hogs are purebred and the remainder are largely very good grades.

Fig. 1. An Adair county feedlot. Beef cattle raising and feeding is an important industry.

Sheep are raised quite generally in the southeastern and western parts of the county. The Shropshire is the most popular breed. The value of the wool produced in 1920 was considerable, as will be evident from a consideration of the figures given in the table showing the total pounds of wool clipped. Some horses are raised in the county, altho only a few make a specialty of breeding horses. Practically every farmer raises a few colts or mules each year. Poultry is raised on all farms and the poultry products are very largely disposed of at the local markets. The value of the poultry products is very large and they add considerably to the income on the farms.

The value of land in Adair county is quite variable, depending upon the location with reference to towns and railroad facilities, the improvements on the farms and the general soil conditions. The price of the farm land ranges from $150 to $400 per acre. In some instances even higher prices have been secured. The average price, however, for the farm land of the county would be about $250 per acre. Improved land on the Tama silt loam will average about $300 per acre, while in the more rolling sections less well adapted for cultivation, as, for example, in areas of the Shelby loam and on the Wabash soils, the price will range from $150 to $250 per acre.

The yields of general farm crops grown in Adair county are usually quite satisfactory, but in many instances proper methods of soil treatment would undoubtedly result in the securing of larger crops. The treatments which should be practiced will vary on the different soils of the county, depending upon the particular conditions and upon the characteristics of the individual types, particularly the topographic features.

In some instances the drainage conditions are not entirely satisfactory and, when this is true, the first treatment needed to bring about satisfactory crop yields will be the installation of tile drains in soils which are too wet. No matter if the cost of the installation of tile is considerable, the expense will be more than warranted by the results secured in the way of larger crop yields.

The soils of the county are all acid in reaction and the application of lime is necessary in all cases in order to secure the best growth of general farm crops, and particularly of legumes. The acidity of the surface soil persists in most cases thruout the subsoil. Only in two instances is there any inorganic carbon in the lower subsoil and in both these cases the amount present is so small that there would be no effect on the needs of the surface soil. It is evident that all the soils of the county should be tested for lime requirement and lime should be applied as shown to be necessary, if crop growth is to be entirely satisfactory. There is considerable experimental evidence and some farm experience showing the beneficial effect of lime when applied to acid soils and showing, also, the large effects of the material in the case of legumes.

Most of the soils of the county are not particularly well supplied with organic matter and the application of farm manure is particularly desirable in order to put the soils in better condition for crop growth. This material brings about large increases in crop yields and is undoubtedly the most valuable fertilizing material which can be used in the county. If farm manure is not available, leguminous crops may be used as green manures and thus serve to keep up the supply of organic matter. Such crops also supply nitrogen to the soil and hence have a double value. It is very necessary that the nitrogen content be kept up in the soils of the county, and in some instances the addition of nitrogenous materials would undoubtedly prove of value. The use of leguminous crops as green manures may, therefore, be very desirable on many of the soils of this county.

The phosphorus supply is low in practically all of the types, and it seems probable that phosphorus fertilizers would prove profitable in many cases. Applications of these materials to small areas are recommended in order that information may be secured regarding their value under individual farm conditions. If profitable increases are secured in such tests, applications may be made to large areas with the assurance of profit.

Complete commercial fertilizers cannot be recommended at the present time for general use in the county, as it is believed that the phosphorus fertilizers will prove quite as satisfactory and less expensive. Such materials may be tested, however, by any farmer who is interested in determining their value. If they prove valuable in increasing crop yields to a profitable extent and particularly if they bring about a more profitable increase than a phosphorus fertilizer, then they may be applied to large areas without fear of injuring the soil.

Erosion occurs to some extent in Adair county and it is very desirable that some method of preventing the washing away of the surface soil should be adopted wherever this injurious action occurs. The formation of gullies occurs to some extent in the rougher uplands and unless these are checked, considerable areas may be rendered useless agriculturally. The carrying away of the surface soil by sheet erosion, while less apparent, is quite as injurious, and unless proper methods are followed to check the action, crop yields will be reduced, owing to the formation of shallow soil conditions. Any expense involved in the prevention of erosion is well warranted by the better results secured from crops grown and by the continued fertility of the soil.

THE GEOLOGY OF ADAIR COUNTY

The original bedrock material underlying the soils of Adair county has been buried so deeply under the glacial deposits of succeeding geological ages that it exerts no effect upon the soil conditions. Only in a few places in the county is there any exposure of this underlying rock. This material appears mostly along the right bank of Middle river.

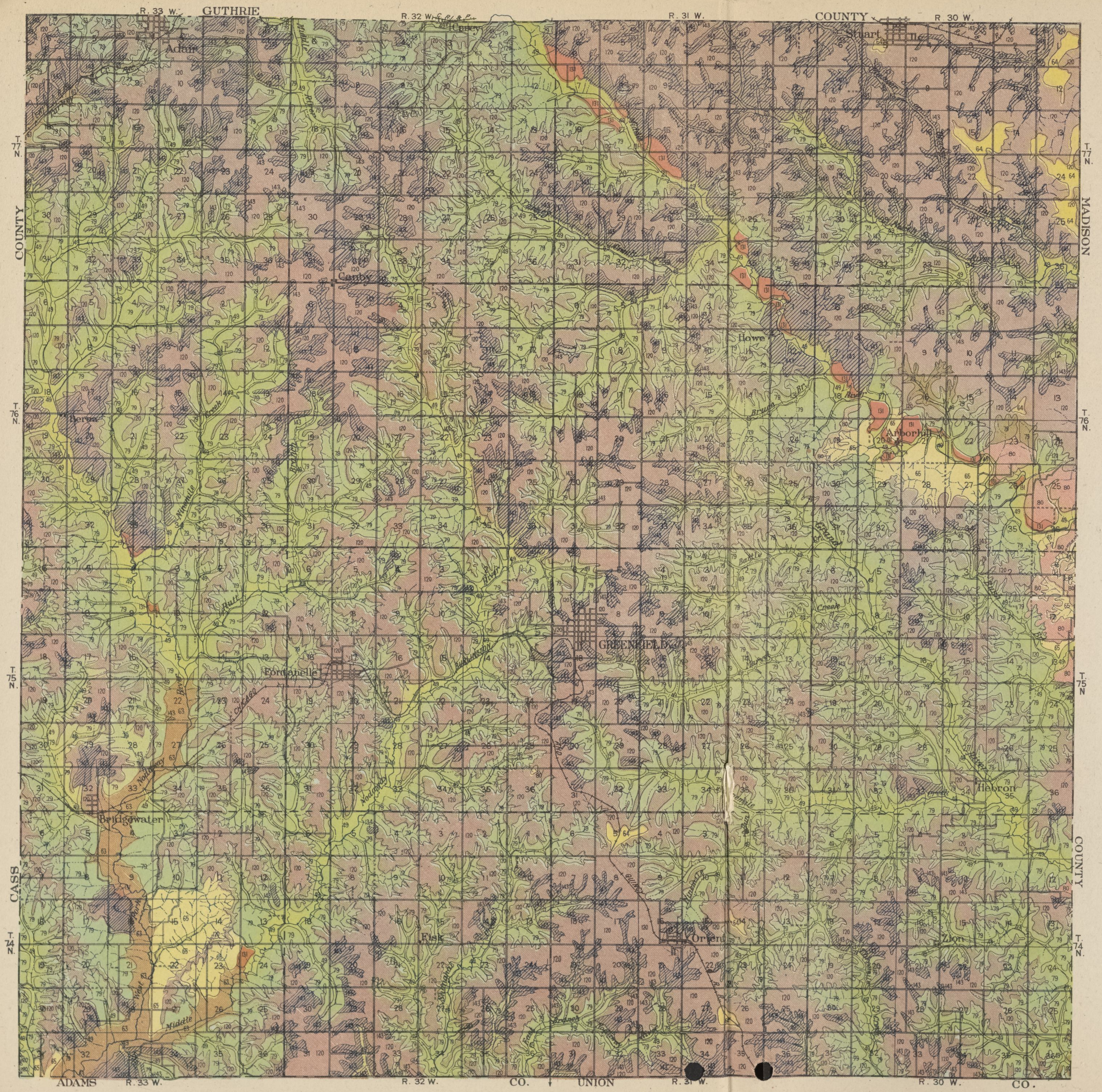
At least once during the glacial age, a great glacier swept over this county and, on its retreat, left behind a vast amount of glacial drift or till. This glacier is known as the Kansan. The drift which it left behind has a thickness estimated at 200 feet, over practically all of the county. The earlier topographic features of the county were very largely obliterated by the glacier upon its advance and hence the depth of the drift deposit is more or less uniform, but there are some places where the deposit is deeper, indicating the location of earlier topographic depressions which were filled by the glacial deposit.

This Kansan drift material is blue in its natural, unoxidized condition, but where it has been exposed to the air, it has changed to a bright yellow or deep reddish-brown. Pockets of sand and gravel occur and boulders are frequently found thruout the drift deposit. The topographic features of the county at the present time are largely the result of weathering and washing of this drift deposit, and apparently the topography was little modified by the later glacial deposit.

The Shelby loam, one of the largest soil types in the county, is derived from the Kansan drift deposit, and the surface soil of this type has been produced thru weathering and the accumulation of organic matter in the Kansan drift. The color of the surface soil has been changed to a dark brown to almost black, but the subsoil is typical of the oxidized Kansan till, being a yellow or reddish-brown. The Lindley loam, a minor type in the county, is also derived in large part from the Kansan drift, the surface soil of the type being partly composed of loess. This type is really a mixture of loess and drift, with the latter predominating, particularly in the subsurface and subsoil layers.

Overlying the glacial deposit, there was laid down, at some time when climatic conditions were very different than at present, a layer of silty material known as loess. The deposition of this material was probably brought about by wind action and probably the entire surface of the county was covered. Since the deposit was made, however, much of the loess has been washed away from the slopes and the underlying glacial drift has been exposed. The areas of Shelby loam which have been mentioned represent that part of the county where the loess has been entirely removed, while the areas of Lindley loam indicate the stage of partial removal of the loess covering. Where the loessial material has not been removed by erosion, the soils of the Tama, Clinton and Grundy series are mapped.

Loess in its unweathered condition is an even-grained material composed largely of silt. It ranges in color from light grayish-brown to yellow-brown.



SOIL MAP OF ADAIR COUNTY

Thomas D. Rice. Inspector, Northern Division. Soils surveyed by Clarence Lounsbury of the U. S. Department of Agriculture, in charge, and T. H. Benton and P. C. Wiechmann of the Iowa Agricultural Experiment Station.

U. S. DEPT. OF AGRICULTURE, BUREAU OF SOILS
Milton Whitney, Chief. Curtis F. Marbut, in charge Soil Survey

IOWA AGRICULTURAL EXPERIMENT STATION
C. F. Curtiss, Director. W. H. Stevenson, in charge of Soil Survey
P. E. Brown, Associate in charge

LEGEND

Drift Soils

79 — Shelby loam

65 — Lindley loam

Loess Soils

120 — Tama silt loam

143 — Tama silt loam (Shallow phase)

80 — Clinton silt loam

64 — Grundy silt loam

Terrace Soils

131 — Judson silt loam

Swamp and Bottomland Soils

49 — Wabash loam

63 — Wabash clay loam

Scale: 1 Inch 2½ Miles

MIDLAND MAP AND ENGINEERING CO.
DES MOINES, IOWA

Due to weathering and the addition of organic matter, the soils formed from the loess are very largely dark in color and, where there has been abundant plant growth and accumulation of vegetable matter under prairie conditions, the soils are quite black in color, as, for example, where they are mapped in the Tama and Grundy series. Where the loess has weathered under forested conditions, organic matter has not accumulated to such a large extent and the soil is gray to light brown, as is the case in the types in the Clinton series. Under the wooded conditions the loess has been washed away to a larger extent, more leaching has occurred and the soil is somewhat poorer in fertility. In all cases the lime has been removed from these loess soils by leaching and they are acid in reaction.

There is a distinct relation between the topographic features of the soil types and the fertility conditions. Thus, the more level soils of the Tama and Grundy series are much richer and more fertile than the Clinton series. The rolling to steep areas of the drift soils are poorer in fertility than even the less productive loess types.

The terrace and bottomland soils of the county are derived very largely from the loess of the upland, altho there is some admixture with the drift from the uplands. Both of these materials are washed down by the rains and deposited in the bottoms, leading to the formation of the Wabash soils, the lighter textured types representing the loessial deposit, while the heavier types are apparently modified by an admixture of drift material.

PHYSIOGRAPHY AND DRAINAGE

In topography Adair county varies from fairly level to strongly rolling, to steep. The larger portion of the county, however, is moderately rolling in topography, and the surface of the loessial area, in particular, is a succession of smoothly rounded hills, sloping gradually to the more level bottomlands. The land in the county slopes either toward the east and southeast or toward the southwest, the area in the entire eastern portion of the county draining into the Des Moines river, while the western portion of the county drains into the Missouri river. The higher land in the county, representing the divide between the tributaries to these two large streams, extends across the county from the northwestern corner near Adair, in a southeasterly direction, almost to the center of the county, then east into Madison county between Middle river and Grand river. A branch of this divide also extends southward from the center of the county, thru Greenfield, to the Union county line.

Northeast of Middle river the topography is less strongly rolling and there are considerable areas of rather level land southeast of Stuart, which are mapped in the Grundy series. The Shelby loam, which borders many of the streams thruout the county, separating the bottomland soils from the rolling Tama of the upland, is frequently rather rough in topography and the slopes to the bottoms may sometimes be very steep. This topographic condition seems to occur more generally along the south sides of eastward and westward flowing streams. Many of the Shelby loam areas are moderately rolling and the slope from the Tama uplands to the Wabash bottoms is usually quite gradual. There are some areas of Lindley loam in the county where the topography is quite rough to rolling, and there is some occurrence of the Clinton silt loam, along the eastern boundary of the county, where the topography is strongly rolling. Some areas of the Shelby loam, the Lindley loam and the Clinton silt loam are too steep for agricultural utilization, but in the main the soils of the county are not topographically unfit for general agricultural use. Erosion occurs to considerable extent in the more rolling areas and the general topographic conditions in the county indicate that some methods must be employed for the prevention or control of destructive erosion, or the washing away of the surface soil.

The bottomlands of the county are rather extensive in total area, but occur only in narrow strips along the various streams and drainageways, and they are level in topography, poorly drained and subject to overflow.

The drainage of the county is brought about mainly by the Middle Nodaway river and its tributaries, and Grand river, Middle river, and North river, with their tributaries. The West Fork Nodaway river is the most important tributary of the Middle Nodaway and, together with Rut Branch and Nine Mile

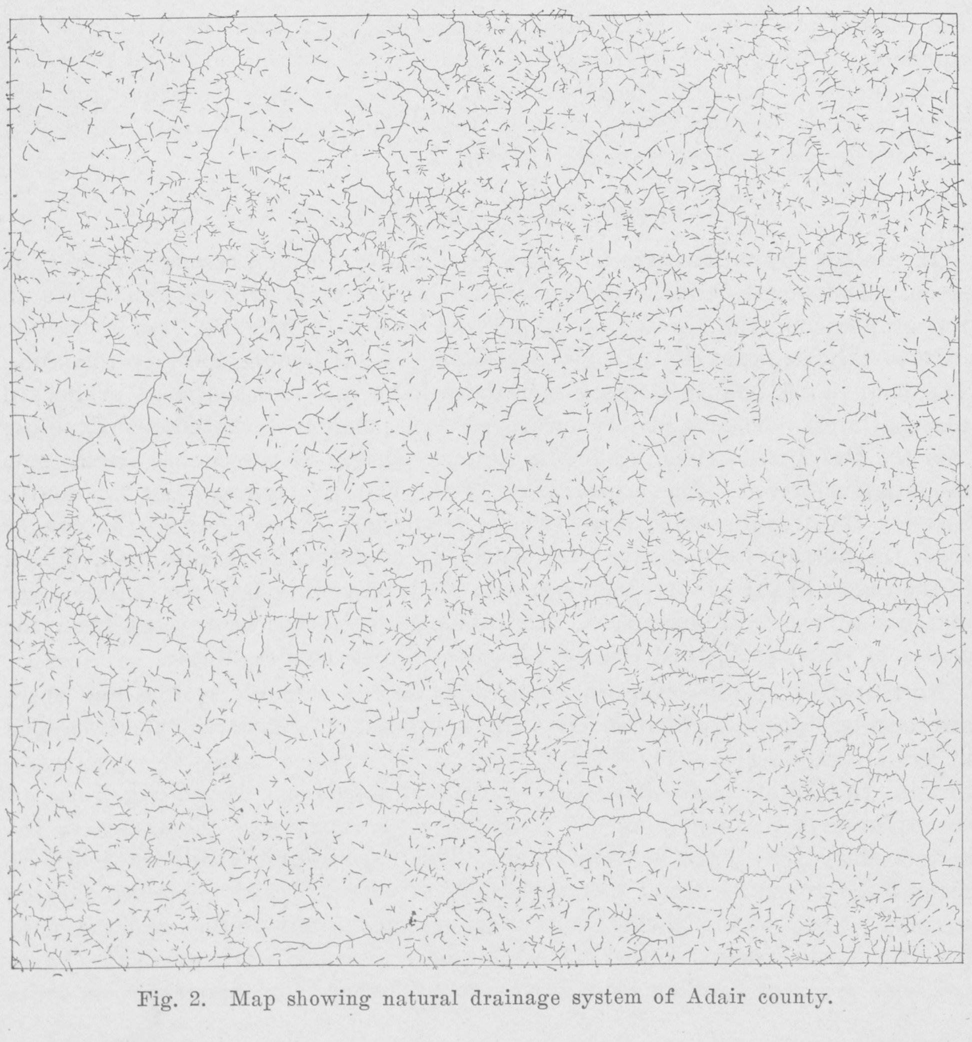


Fig. 2. Map showing natural drainage system of Adair county.

creek, it drains most of the western part of the county. The Middle Nodaway, with its small tributaries, drains the central western part of the county. Shanghai creek and the East Branch Nodaway river and Three-Mile creek drain the southern part of the county. The more important tributaries of the Grand river are Nine-Mile creek, Marvel creek, and Battle creek. Turkey creek and Bruce Branch are the main tributaries of the Middle river. These rivers and their tributaries, together with Grassy Run, bring about the drainage of the entire eastern part of the county, including much of the northern part. The area around Adair drains north thru a branch of the Middle river into Guthrie county. These various streams, with their tributaries, extend to practically all parts of the county. Only in a few small areas is there inadequate drainage, most of the soils being well drained. The areas of Grundy silt loam in the northeastern part of the county are poorly drained, and this is the only soil type which is naturally in need of tiling. There are some instances, however, where the drainage is not entirely satisfactory on some of the other upland types. The Wabash clay loam of the bottoms is poorly drained, also, and the bottomland soils are all subject to overflow. In general, artificial drainage should not be needed to any extent in the county and the installation of a small amount of tile would undoubtedly take care of minor areas where the drainage is inadequate. The accompanying map indicates the extensive drainage system of Adair county and shows that all the soils of the county may be readily drained into the major streams and their tributaries.

THE SOILS OF ADAIR COUNTY

The soils of Adair county are grouped into four classes, according to their origin and location. These are drift soils, loess soils, terrace soils, and swamp and bottomland soils.

Drift soils are formed from the materials carried by glaciers and deposited on the surface of the land when the glacier retreated. They are variable in composition and may contain pebbles and boulders. Loess soils are fine, dust-like deposits made by the wind at some geologic time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them, or by a deepening of the river channel. Swamp and bottomland soils are those occurring in low, poorly drained areas, or along streams, and they are subject to more or less frequent overflow. The extent and occurrence of these groups of soils in Adair county are shown in table II.

Over one-half of the total area of the county is covered by the loess soils, 51.6 percent being occupied by the various types in this group. The drift soils

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN ADAIR COUNTY

Soil Group	Acres	Percent of total area of county
Drift soils	138,944	37.9
Loess soils	188,800	51.6
Terrace soils	1,984	0.5
Swamp and bottomland soils	36,992	10.0
Total	366,720	....

are also extensive, covering somewhat over one-third of the total area of the county, 37.9 percent. There is a relatively small area in terrace in the county and only one terrace type. This soil covers only 0.5 percent of the total area of the county. Swamp and bottomland soils are much more extensive than the terrace types and together they cover 10.0 percent of the county.

There are eight individual soil types in the county and these, together with the shallow phase of the Tama silt loam, make a total of nine separate soil areas. There are two drift soils, four loess types, including the phase of the Tama just mentioned, one terrace soil and two swamp and bottomland types. These various soil types are distinguished on the basis of certain soil characteristics which are described in the appendix to this report and the names denote certain group characteristics. The areas of the various soil types in the county are given in table III.

The Tama silt loam is the largest individual soil type in the county, covering over one-third of the total area in its typical development. Together with the shallow phase of the type, slightly over one-half of the total area is included in this type. The Shelby loam is the second largest soil type in the county, and the largest drift soil. It covers a slightly smaller area than the typical Tama silt loam, occupying slightly over one-third of the total area of the county, 36.4 percent. The Wabash loam is the most extensive bottomland type and is the third largest type in the county, covering 8.4 percent of the total area. The Wabash clay loam is second in area to the Wabash loam, covering 1.6 percent of the county. The Lindley loam is the second drift type, and is minor in area compared with the Shelby loam. It covers 1.5 percent of the total area of the county. The Clinton silt loam and the Grundy silt loam, the remaining loess types in the county, are both minor in area, covering 0.7 and 0.5 percent. The Judson silt loam, the only terrace type in the county, is minor in area, covering 0.5 percent.

The topography of the uplands of the county varies considerably, depending upon the particular soil type which occurs on them. The Tama silt loam and its shallow phase both occur under gently rolling topographic conditions. The Shelby loam is found under more strongly rolling to steep topographic conditions and, in some areas, the type is found in a rough, broken topography.

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN ADAIR COUNTY, IOWA

Soil No.	Soil type	Acres	Percent of total area of county
	DRIFT SOILS		
79	Shelby loam	133,312	36.4
65	Lindley loam	5,632	1.5
	LOESS SOILS		
120	Tama silt loam	136,832	
143	Tama silt loam (shallow phase)	47,872	50.4
80	Clinton silt loam	2,432	0.7
64	Grundy silt loam	1,664	0.5
	TERRACE SOIL		
131	Judson silt loam	1,984	0.5
	SWAMP AND BOTTOMLAND SOILS		
49	Wabash loam	30,976	8.4
63	Wabash clay loam	6,016	1.6
	Total	366,720	——

The Lindley loam is very similar topographically to the Shelby loam and may be strongly rolling to steep in topography. The Clinton silt loam ranges from gently rolling to strongly rolling and in some areas is rather steep. The Grundy silt loam is a more level to very slightly undulating type and it is on the areas of this soil that drainage is sometimes inadequate. The remainder of the upland soils of the county are generally quite adequately drained. The terrace and bottomland types all have a level topographic position and in the case of the Wabash soils on the bottoms, not only is drainage needed to make them productive, but they must be protected from overflow if the best crop yields are to be secured.

THE FERTILITY IN ADAIR COUNTY SOILS

Samples were taken for analyses from each of the soil types in Adair county. The more extensive types were sampled in triplicate, but only one sample was taken in the case of the minor types. All samplings were made with the greatest of care that the samples should represent the particular soil types and that variations due to local conditions and previous treatments should be eliminated. Samples were drawn at three depths, 0—6 2/3", 6 2/3"—20" and 20"—40", representing the surface soils, the subsurface soils and the subsoils, respectively. Analyses were made in all cases for total phosphorus, total nitrogen, total organic carbon, inorganic carbon, and limestone requirement. The phosphorus, nitrogen and carbon determinations were made according to the official methods and the Truog qualitative test was used for the limestone requirement tests. The figures given in the tables are the averages of duplicate determinations on all samples of each type and they represent, therefore, the averages of four to twelve determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil per acre. The phosphorus content of the soils of the county is somewhat variable, ranging from 880 pounds, in the case of the Shelby loam, up to 1,320 pounds in the

TABLE IV. PLANT FOOD IN ADAIR COUNTY, IOWA, SOILS

Pounds per acre of 2,000,000 pounds of surface soil per acre (0"—6 2-3")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
79	Shelby loam	880	2,720	33,108	0	3,333
65	Lindley loam	970	2,680	33,742	0	5,000
	LOESS SOILS					
120	Tama silt loam	1,270	4,130	52,998	0	6,000
143	Tama silt loam (shallow phase)	1,104	3,460	40,567	0	6,000
80	Clinton silt loam	916	2,280	26,644	0	4,000
64	Grundy silt loam	1,158	4,420	58,149	0	5,000
	TERRACE SOIL					
131	Judson silt loam	1,212	3,460	39,659	0	5,000
	SWAMP AND BOTTOMLAND SOILS					
49	Wabash loam	1,064	3,800	46,137	0	2,000
63	Wabash clay loam	1,320	3,740	47,611	0	2,000

case of the Wabash clay loam. There is no apparent relation between the phosphorus content of the soils in the various soil groups. The terrace soil is somewhat higher than the average of the other groups, and the bottomland types average somewhat higher than the upland soils, but there are so few types within each group that definite comparisons should not be made. Variations within groups are even larger than those between the various groups.

It is hardly possible from the analyses of these soils to draw any conclusions regarding the relation between the soil series and texture and the phosphorus supply. There are too few soil types represented in the county and only in one case are there soils in the same series of different textures. It might be noted, however, that the Grundy silt loam and the Tama silt loam are much better supplied with plant food in general than the Clinton soil of the same texture. The Tama silt loam and the Grundy are very much alike, as is generally the case. There is very little difference in the Lindley and Shelby loams, but these are poorer in plant food than the loess soils, which may be due in part to the series in which they occur and in part to the texture. Silt loams would ordinarily be expected to prove somewhat richer than loams.

There is undoubtedly some relation between plant food content and soil series, because of topographic differences. Thus, the Grundy silt loam is richer than the Clinton, because of its topography; at least, this may be partly the reason for the larger amount of plant food. A further reason is that the Grundy has been developed under prairie conditions, while the Clinton has been developed under wooded conditions. The shallow phase of the Tama is, of course, lower in plant food than the typical Tama, as would be expected, owing to the fact that it has been formed by the washing away of much of the surface soil. The two soils of the Wabash series differ somewhat in plant food, particularly from the phosphorus standpoint. The clay loam is higher than the loam in this constituent, which is a direct result of different textural conditions. It might be expected that the bottomland types would be somewhat higher than the upland soils, owing to their level topographic position and to the fact that crop production has been less on these types in the past and there has been less removal of plant food. Similarly, it might be expected that the Grundy silt loam would be higher than the Clinton silt loam in this constituent. The differences between the supply in the loess soils and the drift types may go back to the origin of the soils, altho the origin is probably secondary in consideration to the conditions to which the soils have been subjected since their formation.

In general, it is apparent from these analyses that there is no large supply of phosphorus in the soils of Adair county, and phosphorus fertilizers will certainly be needed on these soils in the near future if satisfactory crop yields are to be secured. It is quite possible, however, that phosphorus carriers will prove of considerable value at the present time on many of the soils, and such materials must certainly be taken into account in planning systems of permanent fertility for the county.

It should be emphasized that the total supply of phosphorus in the soils does not show how much of this element is available for the use of crops, and the figures given in the tables merely serve to indicate the store of this element which may be drawn upon more or less rapidly, depending upon the soil conditions which affect the production of available plant food. It is generally conceded, however, that when the total supply of any plant food constituent reaches a low figure there will be a very small production of that element in an available form. In other words, the reduction in total content of phosphorus will mean a very much more rapid reduction in the production of available phosphorus; hence, when the total supply of this element in the soil is low, it is almost certain that crops will not secure sufficient phosphorus in an available form to bring about the best growth. But even when the total amount of phosphorus is considerable, the supply of available phosphorus may be lacking if the soil conditions are not such that there is a rapid transformation of unavailable to available phosphorus.

It is quite reasonable, therefore, to conclude from the analyses given that phosphorus fertilizers may prove of value on many of the soils of the county at the present time, and especially on those types which seem to be rather low in this constituent. Furthermore, the same fertilizers may prove of value on the soils which are better supplied with phosphorus and in no case is the amount of phosphorus sufficient to keep crops supplied for any extended period, even if it were all made available as rapidly as it could be utilized. Farmers are urged to test the use of phosphorus fertilizers on their own soils and thus determine for their own particular farm conditions the need of phosphorus, and which phosphorus fertilizer should be applied, whether rock phosphate or acid phosphate. Such tests should be carried out on a small area and if profitable crop increases are secured, then the same materials may be applied to larger areas with the assurance of profit.

The nitrogen content of the soils of the county is quite as variable as the phosphorus supply, ranging from 2,280 pounds, in the Clinton silt loam, up to 4,420 pounds in the Grundy silt loam. There is no relation between the nitrogen content of the various types and the different soil groups, and no comparisons can be made, owing to the small number of soil types and the small differences which occur. Neither is it possible to draw any conclusions regarding the relation between the soil series and the soil textures from the nitrogen standpoint. The Grundy and Tama soils are, however, higher in nitrogen than the Clinton soils and they are likewise higher than the Shelby and Lindley soils of the drift upland. This difference is very largely due to the conditions under which these soils have been formed, and is indicated also, by the color of the soil. There may be some effect of the texture, also, but if so, such effects cannot be noted in the comparisons which can be made. There is very little difference between the clay loam and the loam in the Wabash series, the only place where an actual textural comparison can be made.

While the soils of this county seem to be in general fairly well supplied with nitrogen, there is no large amount present in any case and this element will certainly need to be considered in planning systems of permanent fertility for the county. Some nitrogenous fertilizing material must undoubtedly be used at regular intervals on these soils if the nitrogen supply is to be kept up.

Farm manure is a very important nitrogenous fertilizer, returning to the soil, as it does, considerable amounts of nitrogen which have been removed by the various crops utilized in the feed. The proper utilization of crop residues aids in keeping up the nitrogen supply in the soil and these materials should always be very carefully utilized.

On many livestock farms, where the supply of manure is insufficient to provide for all the soils, and on the grain farm, where manure is lacking, the nitrogen content of the soil should be increased and kept up by turning under well inoculated leguminous crops as green manures. When such crops are well inoculated, they draw a large portion of their nitrogen from the atmosphere, and when turned under in the soil, they serve as nitrogenous fertilizers. The actual amount of nitrogen supplied to soils by this means will vary to a considerable extent, depending upon the thoroness of the inoculation of the legume, the amount of crop growth secured, and the amount turned under in the soil. Many legumes may be used as green manures to serve as nitrogenous fertilizers and such materials are undoubtedly the cheapest and most satisfactory source of nitrogen which can be employed.

The organic carbon content of soils is a measure of the organic matter contained in them and the amount of this constituent present is indicated quite definitely by the color of the soil. Furthermore, there is a very close relation between the organic carbon and the nitrogen in soils and hence a relation of nitrogen to color. If the soil is black in color, the amount of organic carbon and nitrogen present will be high. If the soil is light in color, there is undoubtedly a deficiency in these constituents.

Most of the soils of Adair county are fairly well supplied with organic carbon, as is indicated by their typical dark brown to black color. There are a few cases, however, where the amount of organic matter is rather low, for example, in the Clinton, Shelby and Lindley soils. The amount of organic carbon ranges from 26,644 pounds, in the Clinton silt loam, up to 58,149 pounds in the Grundy silt loam. It is apparent that the relations mentioned in the case of nitrogen very largely hold true for the organic carbon, and the more level upland loess soils developed under prairie conditions are richer in organic carbon than the more rolling types developed under wooded conditions. It is hardly possible from the results given in the table to draw any conclusions regarding the relations between organic carbon and nitrogen and the texture of the soil, owing to the fact that so few soils of the same series and of different texture are found in the county.

The relation between the carbon and nitrogen in soils gives rather definite evidence of the rate at which plant food is being made available. It would seem that in this county the relation between these constituents should be such that a satisfactorily rapid production of available plant food would occur. There are several instances, however, where the relation between these constituents might be improved thru the addition of organic matter, and where the production of available plant food should take place more rapidly. The fact that applications of manure prove of so much value on most of these soils is an indication of the fact that the production of available plant food might be stimulated with profitable effects on crop yields. This is evidently the cause, in part, at least, of the beneficial effect of applications of manure, but there are other factors involved, of course, one of the most important being the addition of bacteria, the result of which is an increased production of available plant food. It is usually conceded that on soils fairly well supplied with organic matter, the value of manure may be due in large part to the introduction of bacteria and the stimulation of bacterial action.

The maintenance of the organic matter content of the soils of the county is of considerable importance, and the utilization of farm manure for this purpose is most desirable. Crop residues should also be utilized to aid in keeping up the supply of organic matter, and the growing of legumes and turning under of part or all of the crop is a further method of supplying organic matter to the soil. On grain farms where farm manure is not available, leguminous green manure crops should be used as substitutes for that material in order to keep up the supply of organic matter.

There is no inorganic carbon in any of the soils of the county, and they all show a limestone requirement according to the qualitative Truog test. There is some variation in the acidity in the various soil types, but the figures given in the table should be considered merely indicative of the needs of the various soil types. As soils vary widely in lime requirements, different tests of the same type, even from the same field, may show rather wide variations. It is quite evident that the soils of this county should all be tested for acidity.

Legumes will not grow satisfactorily on acid soils and the application of lime may mean the difference between a profitable legume crop and failure of the crop. The effect of lime will show on the succeeding grain crops of the rotation and, in general, the beneficial effects of liming are apparent on all crops of the rotation, but are particularly evident on legumes. The soils of this county should be tested at the present time and tests will also be needed in the future in order to keep up the supply of this constituent. It is usually suggested that the soils be tested once in four years and lime applied preceding the legume crop of the rotation. Farmers of Adair county will need to see to it that lime is applied to their soils now as needed, and also at regular intervals in the future, if they are to secure satisfactory crop yields and keep their soils permanently productive.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface and 6,000,000 pounds of subsoil per acre. The amount of plant food present in the lower soil layers has little effect upon the fertility of the surface soil, unless there is a large content of some particular element. None of the soils in Adair county seem to have any large supply of plant food in the lower layers and hence it is hardly necessary to consider these results in detail.

The results of the analyses of the surface soils seem to indicate quite definitely the needs of the soils of the county and the conclusions which were drawn from these analyses are not modified to any extent by a consideration of the plant food present in the lower soil layers. The phosphorus content of the soils is low thruout the 3-foot section and there is need for the addition of phosphorus fertilizers, if these soils are to be kept supplied with this constituent. In all probability phosphorus fertilizers would prove of value on many of the soils

TABLE V. PLANT FOOD IN ADAIR COUNTY, IOWA, SOILS
Pounds per acre of 4,000,000 pounds of subsurface soil per acre (6 2-3"—20")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
79	Shelby loam	1,500	3,213	39,572	0	3,333
65	Lindley loam	2,290	1,760	19,656	0	3,000
	LOESS SOILS					
120	Tama silt loam	1,590	6,560	78,878	0	6,000
143	Tama silt loam (shallow phase)	916	3,920	47,283	0	4,000
80	Clinton silt loam	1,482	2,800	31,122	0	5,000
64	Grundy silt loam	1,454	4,560	63,882	0	4,000
	TERRACE SOIL					
131	Judson silt loam	2,182	5,600	63,663	0	5,000
	SWAMP AND BOTTOMLAND SOILS					
49	Wabash loam	1,886	6,600	84,630	0	2,000
63	Wabash clay loam	2,614	8,600	127,218	0	2,000

in the county at the present time, and tests of these materials are to be recommended. The supply of nitrogen is not high and materials supplying nitrogen should be added to these soils at regular intervals. The organic matter content must also be kept up and the use of farm manure and leguminous green manures will maintain the supply both of nitrogen and of organic matter. The application of manure to these soils is particularly desirable and will bring about large effects on crop yields.

The soils are all acid in reaction and applications of lime are necessary in order to put the soils in the best condition for the growth of all crops and particularly for the satisfactory growth of legumes. It is very important that every soil in the county be tested for acidity and that lime be applied, as necessary, before a legume is grown. The amount of lime which is needed on the soils of the county will be determined very largely by the tests of the surface soils. The fact that the lower soil layers are also acid means that it will be necessary to apply lime at regular intervals in the future in order to bring about a complete neutralization of all acidity thru the soil section. The addition of sufficient lime to take care of the acidity in the surface layer will, however, be sufficient for the satisfactory growth of legumes at the present time.

TABLE VI. PLANT FOOD IN ADAIR COUNTY, IOWA, SOILS
Pounds per acre of 6,000,000 pounds of subsoil per acre (20"—40")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
79	Shelby loam	2,451	3,160	36,031	10,300	Basic
65	Lindley loam	2,829	3,480	40,950	0	5,000
	LOESS SOILS					
120	Tama silt loam	2,061	5,460	60,879	0	6,000
143	Tama silt loam (shallow phase)	807	2,820	32,760	0	3,000
80	Clinton silt loam	3,393	2,820	32,760	0	5,000
64	Grundy silt loam	2,910	4,200	52,416	0	2,000
	TERRACE SOIL					
131	Judson silt loam	2,787	4,200	46,683	0	5,000
	SWAMP AND BOTTOMLAND SOILS					
49	Wabash loam	2,667	12,240	24,570	0	3,000
63	Wabash clay loam	2,787	8,400	136,853	1,230	Basic

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Adair county in the attempt to learn something of the fertilizer needs of the soils of the county and to secure indications of the value of certain fertilizer materials. These experiments were carried out on the Tama silt loam and the Shelby loam, the two major soil types in the county. The results of experiments on the Tama silt loam in Cedar and Marshall counties and on the Shelby loam in Wayne county are also included, inasmuch as the types are the same as the main types in Adair county and the results very largely confirm those secured in the experiments on the same soil types from Adair county.

The treatments used in all of these experiments included the application of manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. The amounts of these materials used were the same as those employed in the field tests and hence the results of these greenhouse experiments may be considered to indicate rather definitely the results which may be secured in the field. Manure was applied at the rate of 8 tons per acre, lime was added in sufficient amounts to neutralize the acidity of the soil and supply 2 tons additional, rock phosphate was added at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in the various experiments, the clover being seeded about one month after the wheat was up. In several cases the clover yields only are given in the tables, as the wheat yields were not secured.

The green weights of clover on the Shelby loam from Adair county are given in table VII, the figures being the averages of the yields on the duplicate pots. The application of manure brought about a very large increase in the yield of clover, and apparently this material is an extremely valuable fertilizer on this soil. The addition of lime along with manure increased the clover yield to some extent, as might be expected, as this soil is uniformly acid in reaction and in need of lime for the best growth of legumes. The addition of phosphate fertilizers and the complete commercial fertilizer all proved of value on the clover, the increases being quite pronounced in all cases. The results are too close together, however, to permit of any conclusions being drawn regarding the relative merits of the various materials. It would seem, however, that the phosphorus carriers would prove more profitable than the complete brands of fertilizers, inasmuch as these latter materials are more expensive and apparently do not bring about any larger effects.

The yields of clover on the green basis in the greenhouse experiment on the Tama silt loam from Adair county are given in table VIII. The addition of

TABLE VII. GREENHOUSE EXPERIMENT, SHELBY LOAM, ADAIR COUNTY

Pot No.	Treatment	Green weight clover in grams
1	Check	18.14
2	Manure	99.79
3	Manure+Lime	131.54
4	Manure+Lime+Rock phosphate	165.56
5	Manure+Lime+Acid phosphate	167.83
6	Manure+Lime+Complete commercial fertilizer	165.56

TABLE VIII. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, ADAIR COUNTY

Pot No.	Treatment	Green weight clover in grams
1	Check	65.77
2	Manure	92.90
3	Manure+Lime	129.27
4	Manure+Lime+Rock phosphate	156.49
5	Manure+Lime+Acid phosphate	172.36
6	Manure+Lime+Complete commercial fertilizer	161.72

manure proved distinctly profitable on the clover grown on this soil type and tho the soil is apparently very well supplied with organic matter, manure seems to be a very profitable fertilizer. The application of lime increased the yield of clover somewhat and quite generally the Tama silt loam seems to respond to this material, especially when legumes are grown. The phosphorus carriers and the complete commercial fertilizer all had some effect on the clover, the acid phosphate showing up somewhat better than the other materials. However, the differences are not very great and it is hardly possible to conclude which material should be employed on this soil. It would seem that one of the phosphorus carriers would probably prove more profitable than the complete fertilizer, inasmuch as that material is so much more expensive. Apparently this soil will respond to applications of manure, lime and phosphorus fertilizers and it must remain for field tests to determine which particular phosphorus carriers should be used.

The results of the experiment on the Shelby loam from Wayne county are given in table IX, the weight of clover in this experiment being given on the

Fig. 3. Greenhouse experiment with wheat on Shelby loam in Wayne county.

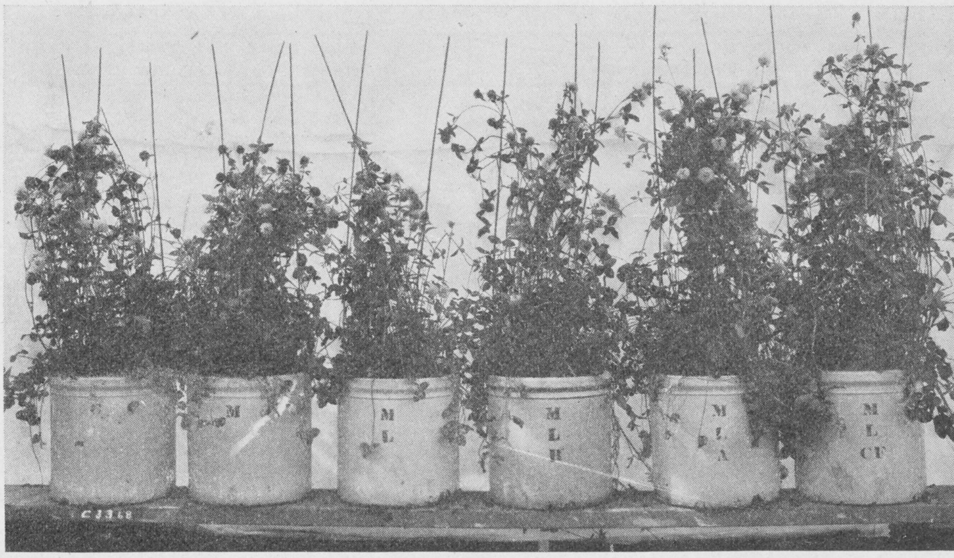


Fig. 4. Greenhouse experiment with clover on Tama silt loam, Marshall county.

dry basis. Again, as on the Shelby loam from Adair county, the application of manure brought about a distinct increase in the growth of clover. Here, however, the wheat yields were secured and a large increase in this crop from the use of manure was also noted. The lime showed no effect on the wheat, but did increase the clover, as in the preceding experiment. It would not be expected that lime would bring about any particular effect on the grain crop, the influence of this material being exerted mainly upon the legume grown in the rotation. The addition of the phosphate fertilizers and the complete commercial fertilizer proved of value on this soil, there being very little choice, however, between the three materials. The yield of clover on the commercial fertilizer pot was not secured, so the comparison of the use of these materials was not complete. It seems, however, that phosphorus fertilizers would prove of more value on this soil than the complete materials. These results confirm those secured on the same soil type in Adair county and show the large value of manure in increasing the yields of crops grown on this type. Lime is found to be of value for clover and there are indications that phosphorus fertilizers would bring about profitable crop increases. Apparently these materials will prove of greater value than the more expensive complete fertilizers. Field tests are needed to determine the relative value of rock phosphate and acid phosphate.

TABLE IX. GREENHOUSE EXPERIMENT, SHELBY LOAM, WAYNE COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Dry weight clover in grams
1	Check	18.0	36.28
2	Manure	28.0	40.82
3	Manure+Lime	28.0	43.09
4	Manure+Lime+Rock phosphate	29.0	45.36
5	Manure+Lime+Acid phosphate	28.5	45.36
6	Manure+Lime+Complete commercial fertilizer	30.2	....

TABLE X. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, MARSHALL COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Dry weight clover in grams
1	Check	19.75	45.36
2	Manure	23.00	45.36
3	Manure+Lime	23.50	49.89
4	Manure+Lime+Rock phosphate	24.00	54.43
5	Manure+Lime+Acid phosphate	27.50	72.63
6	Manure+Lime+Complete commercial fertilizer	24.00	63.50

The results of the experiment on the Tama silt loam from Marshall county are given in table X. The beneficial effect of applying manure to this soil is shown up very definitely in this experiment in the case of the wheat, but the clover does not seem to be increased in this particular case. The results on the same soil type, however, from Adair and Cedar counties, show a large effect on the clover from the use of manure. It would seem, therefore, that this material would undoubtedly prove of much value on the various crops of the rotation and that manure should be considered the most valuable fertilizing material for use on this soil. The addition of lime increased the yield of clover, but had little effect on the wheat, which is what would be expected because of the fact that wheat is not particularly sensitive to acid conditions. The addition of the phosphate fertilizers and the complete commercial fertilizers proved beneficial both on the wheat and on the clover. The acid phosphate showed up the best in the case of both crops, the complete commercial fertilizer proving somewhat superior to the rock phosphate on the clover, while

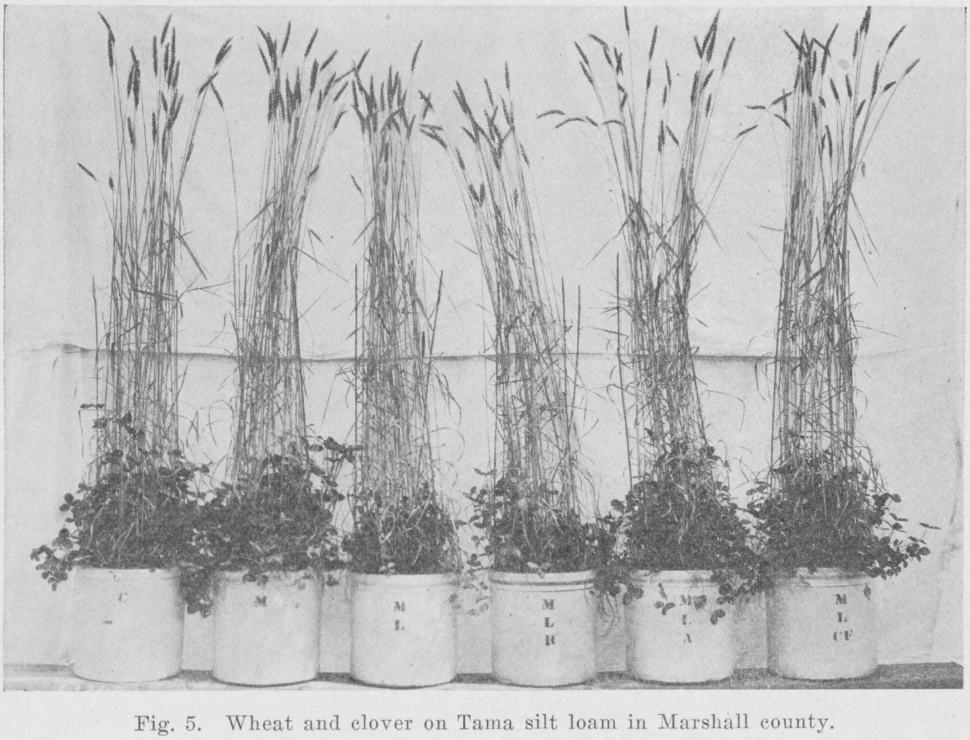


Fig. 5. Wheat and clover on Tama silt loam in Marshall county.

TABLE XI. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, CEDAR COUNTY

Pot No.	Treatment	Green weight clover in grams
1	Check	4.53
2	Manure	43.09
3	Manure+Lime	58.96
4	Manure+Lime+Rock phosphate	58.96
5	Manure+Lime+Acid phosphate	106.59
6	Manure+Lime+Complete commercial fertilizer	111.13

on the wheat these two materials gave the same results. The differences, however, are not large in any case and it would seem that, while the phosphorus fertilizers would undoubtedly prove superior to the complete brands, further tests would be necessary before drawing definite conclusions regarding the relative merits of rock phosphate and acid phosphate.

The results of the experiment on the Tama silt loam from Cedar county are given in table XI. Again the weight of the clover only was secured, and on a green basis. The results, however, confirm those secured on the same soil type in Adair county and in Marshall county. The large effect of manure is particularly evident in this experiment and the addition of lime along with manure showed a large effect on the clover, as was noted on all the preceding tests. The rock phosphate showed no indications of value, but the acid phosphate and complete commercial fertilizer both brought about large increases in crop yields. The complete brand showed up somewhat better than the acid phosphate, but the difference is hardly large enough to warrant conclusions. Furthermore, the acid phosphate costs less than the complete commercial fertilizer and would probably prove the most economic material. These results would indicate a superior value for the acid phosphate over rock phosphate, as was also shown in the experiment on the same type in Marshall county. However, field tests are needed before definite conclusions are drawn along this line.

It is quite apparent from these greenhouse experiments as a whole that the Tama silt loam and the Shelby loam, the two most extensive soil types in Adair county, will respond to applications of manure, lime and phosphorus fertilizers.

FIELD EXPERIMENTS

Field experiments have been begun in Adair county, but they have not been under way long enough yet to yield results; hence, none of these experiments can be reported at present. The results obtained in Black Hawk county on the Tama silt loam, one of the important soil types in the county, may be included in this report, as the results secured are undoubtedly indicative of the needs of this soil type in general and may serve to indicate the treatments which should be practiced in the field. The data obtained on the experiments in Adair county will be given in a later publication. They are planned on much the same basis as the experiments now in progress and all these field experiments are laid out on land which is representative of the individual soil types. They are permanently located by the installation of corner stakes and the fertilizing materials which are tested are the same in all cases.

These fields quite generally include tests under the livestock and grain systems of farming, manure being applied in the former and crop residues utilized instead of manure in the latter system. The fertilizing materials used include manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. On the grain system the same fertilizers are used, substituting the crop residues for the manure. In the field experiments thus far reported, only the livestock system experiments are given, as the crop residues have not been applied in sufficient amount to have any effect on the crop production. Manure is applied at the rate of 8 tons per acre once in a four-year rotation. Limestone is added in sufficient amounts to neutralize the acidity of the soil and supply 2 tons additional. Rock phosphate is added at the rate of 2,000 pounds per acre once in the rotation, acid phosphate at the rate of 200 pounds per acre annually and a standard 2-8-2 complete commercial fertilizer at the rate of 300 pounds per acre annually. The plots in these experiments are 156′ 6″x20′ in size, representing, therefore, areas of 1/10 of an acre.

THE HUDSON FIELD

The results of the experiment on the Hudson field in Black Hawk county, on the Tama silt loam, are given in table XII. The crop yields were not secured on this field in 1921, owing to an oversight on the part of the cooperator, but the yields for 1918, 1919, and 1920, are given in the table. The beneficial effect of manure, lime and phosphorus fertilizers on the Tama silt loam are shown up quite definitely in these results. Manure seems to be of particular value on this soil for corn and oats, and, if the indications from the greenhouse experiments were confirmed in the field, the clover would also show large effects from the use of this material. Apparently manure is a particularly valuable fertilizing material for the growth of general farm crops. It is interesting to note the beneficial effect of lime on the corn and oats on these plots, increases being secured in every case from the use of this material. It might be expected that the lime would show up particularly well on clover, but ordinarily the grain crops of the rotation do not seem to be benefited materially by it. Apparently, however, the improvement of the reaction of this soil is of value in bringing about larger yields of general farm crops.

Rock phosphate, acid phosphate and the complete commercial fertilizer all brought about beneficial effects on the crops grown. The difference between the effects of these various materials are, however, too small to be conclusive and in fact there are some variations in the results secured on the same crops in different seasons. It would seem evident, however, that phosphorus fer-

TABLE XII. FIELD EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY, HUDSON FIELD

Plot No.	Treatment	Corn bu. per acre 1918	Oats bu. per acre 1919	Clover tons per acre 1920
1	Check	45.8	47.6	53.2
2	Manure	49.3	54.7	62.8
3	Manure+Lime	54.4	59.2	67.4
4	Manure+Lime+Rock phosphate	56.5	64.9	73.3
5	Manure+Lime+Acid phosphate	57.4	62.2	73.3
6	Manure+Lime+Complete commercial fertilizer	58.5	57.5	72.4

tilizers would probably prove of value on this soil in many cases at the present time and tests of phosphorus carriers are urged in order to determine the exact value from the use of these materials, as well as to learn which particular phosphorus carrier should be employed. The addition of complete commercial fertilizers to this soil does not seem to be of as much value as the use of phosphorus carriers.

THE NEEDS OF ADAIR COUNTY AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

The field experiments which have recently been started in Adair county will eventually yield quite definite information regarding the needs of the soils of the county. These experiments must be carried on, however, for a number of years before data is secured which will be conclusive enough to permit of the making of definite recommendations. For the present, the suggestions which are offered for the improvement of the soils of the county and the increasing of crop production are based on the results of the laboratory and greenhouse tests which have been described earlier in this report, and on a field experiment from another county, on a soil type which is the same as one of the most extensive types in this county. The results from this field experiment may be considered to indicate quite definitely the needs of this particular soil and the results which have been secured in this test very largely confirm the results of the laboratory and greenhouse tests which have been carried out on the samples from Adair county. No definite recommendations are made in this report, however, except such as have been tested to some extent by indi-

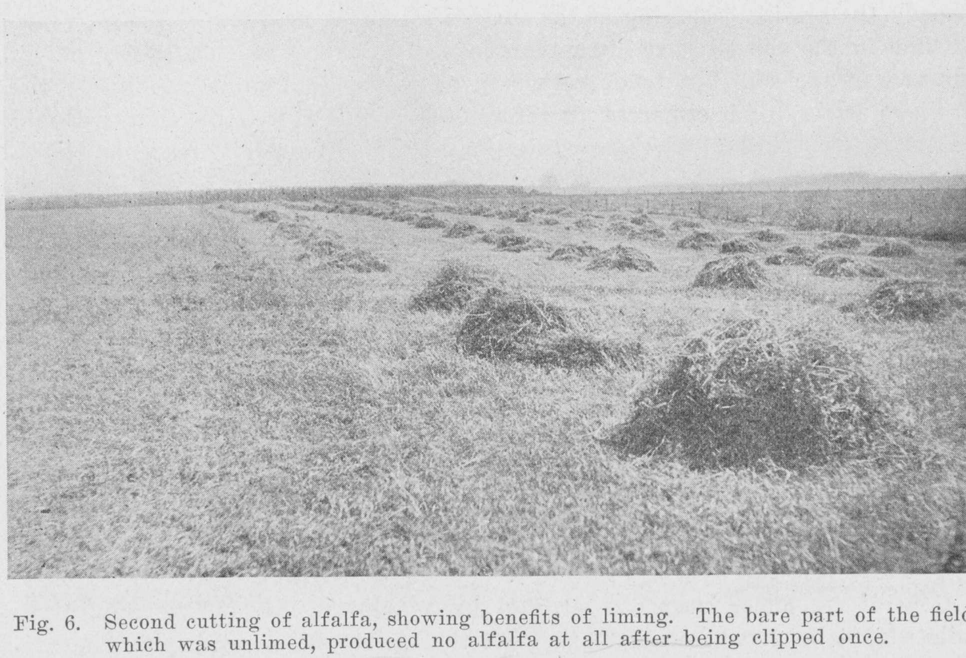


Fig. 6. Second cutting of alfalfa, showing benefits of liming. The bare part of the field, which was unlimed, produced no alfalfa at all after being clipped once.

vidual farmers and have been proved to be of practical value by actual farm experience.

In those cases where the beneficial effects of certain methods of soil treatment have not been definitely proved by practical experience, the recommendation is made that the materials in question be tested by individual farmers. When such tests are carried out on the farm, definite information may be secured regarding the desirability of using the particular fertilizing materials under the special soil conditions. Tests are being carried out by some farmers at the present time and they are finding that the work is not complicated, and provides them with valuable information. The Soils Section of the Iowa Agricultural Experiment Station is ready to aid farmers who are interested in carrying out tests of fertilizing materials and, until the field experiments now under way are more complete, the best suggestion which can be offered is the desirability of testing various materials on small areas. The suggestions which are given in the following pages may be put into operation under any farming conditions.

LIMING

The soils of Adair county are all acid in reaction and therefore are all in need of lime. There are only two types which are basic, even in the subsoil, and in those cases there is not a large content of lime present. These types are the Shelby loam and the Wabash clay loam. The surface soils and subsurface soils of both these types are acid. Furthermore, other samples of these types would undoubtedly prove acid in reaction in the subsoil, inasmuch as the occurrence of lime in these soils is not typical. However, even if the presence of lime in these soils were constant in the lower soil layers, there would not be a large effect on the needs of the surface soils and the use of lime to remedy the acidity occurring at the surface would be necessary. The presence of lime in the subsoil is of little significance, inasmuch as lime rarely moves upward in the soil, but tends rather to be washed out quite rapidly in the drainage water. It is apparent, therefore, that all the soils of the county should be tested for acidity and that applications of lime should be made as shown to be necessary.

Because of the constant removal of lime from well-drained, cultivated and cropped soils, one application of lime is not sufficient to keep the soils supplied indefinitely, and tests must be made at regular intervals. It is suggested that the soils of the county should be tested for lime requirement at least once in a four-year rotation, and that this material be applied as needed preceding the legume crop of the rotation. In this way the largest effects from the application will be secured. Farmers may test their own soils for acidity, but it will be much more satisfactory if they will send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. In this way they will be sure to apply the amount of lime needed on the particular soil and may avoid an insufficient application or an unnecessarily large addition.

General recommendations regarding the amount of lime to be applied to soils cannot be given, owing to the fact that soils vary so widely in lime requirement. Even in the same soil type, and frequently in the same field, there will be considerable variation in the acidity of the soil. The figures given in the tables discussed earlier in this report, even tho they are the averages of tests made on several samples, are merely indicative of the needs of the individual soil types and should not be interpreted to show the exact requirements of the same soil types thruout the county. Before lime is applied to any soil, that particular soil should be tested and its exact lime need determined.

The beneficial effects of lime on soils are becoming more and more generally appreciated. Clover and alfalfa and some other legumes are particularly sensitive to a lack of lime in the soil and in some instances refuse to make a satisfactory growth unless lime is applied. Many experiments and much farm experience have shown the large crop increases obtainable by the application of lime on legumes. In many cases other farm crops are also benefited by the application of lime, even tho they are apparently not so sensitive to acid conditions. Thus, there is experimental evidence of the value of lime on soils from the standpoint of yields of corn and oats. With these crops, lime proves valuable, probably because of indirect effects on the soil conditions. Where greater legume growth is secured, the succeeding grain crops will be benefited and this may be considered an indirect effect of lime.

In general, it may be said that lime proves beneficial on acid soils because of the neutralization of acid conditions which tend to restrict crop growth, because of the improvement of the physical condition of the soil, and because of the stimulation of beneficial bacterial action. There is a constant production or increase in acidity in soils, due to the washing away of basic compounds,

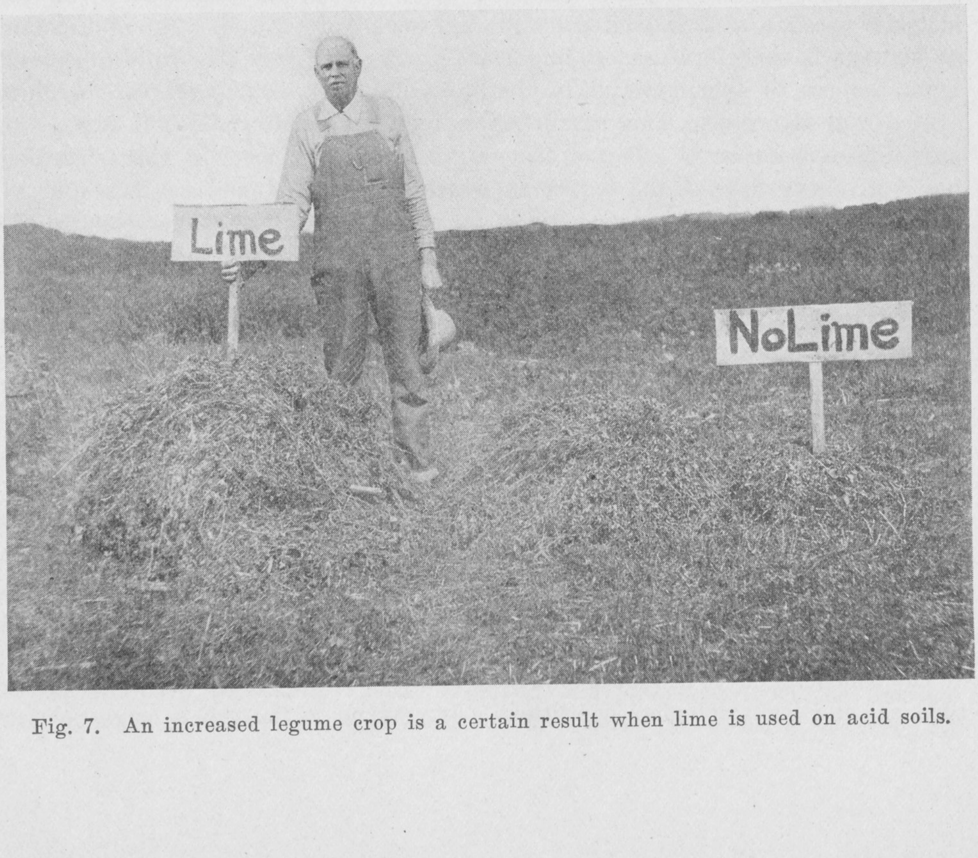


Fig. 7. An increased legume crop is a certain result when lime is used on acid soils.

the utilization of bases by the crops grown, and the production of acids in the decomposition of organic matter, and the growth of general farm crops, particularly of legumes, will not proceed as satisfactorily where these acid conditions occur. Lime also increases crop growth by improving the physical condition of soils, opening up heavy, impervious types and making light, open soils more retentive of moisture and less subject to losses by leaching. All the desirable bacterial action is decreased by acidity and, in fact, the accumulation of acids in soils may cut down the production of available plant food to such a point that crops will suffer. The bacterial conditions in soils are improved by the addition of lime and hence the production of available plant food is increased. Probably under most soil conditions the addition of lime proves of value because of the chemical, physical and bacterial effects combined, but in some instances, and particularly in the case of legumes, the chemical effects are undoubtedly of major importance.

The expense of the application of lime is more than warranted by the value of the increased crop yields, and the farmers of Adair county may be assured that the testing of their soils and the use of lime when they are acid will yield profitable returns. Further recommendations regarding the use of lime on soils, losses by leaching, and other information connected with liming are given in Bulletin 151 of the Iowa Agricultural Experiment Station. The list of companies from which the material may be secured is given in circular 58.

MANURING

The soils of Adair county are not supplied with any considerable quantities of organic matter and in some instances there is a rather small amount of this material present, as is indicated by the light color of the soil. The application of manure is therefore a most important farm practice. The results secured from the use of this material in the way of better crop yields are definite evidence of its value. There is no other fertilizing material which has given anything like as large effects. The experiments reported in the preceding pages give evidence of the extent to which crop yields may be increased by its use, and the practical experience of many farmers in the county confirm the results of these tests.

On the soils which are rather poorly supplied with organic matter according to the analyses, manure gives especially large returns. Thus, the value of the material shows up particularly well on the Clinton silt loam, the Shelby loam and the Lindley loam, but even on those types which seem to be fairly well supplied with organic matter, crop yields are increased to a large extent by the use of farm manure. The results secured on the Tama silt loam bear evidence of the value of this material on types which are not low in organic matter, as the Tama silt loam is fairly well supplied with this material. The farmers of Adair county should keep in mind the large fertilizing value of farm manure and should see to it, therefore, that all the manure produced on their farms is carefully preserved and applied to the soils, if they are to keep up crop growth and maintain their soils permanently fertile.

The beneficial effect of manure on soils is due to its influence on the chemical, physical and bacteriological conditions. It returns to the soil a large portion of the plant food constituents which have been removed by the crops grown and utilized for feed. Hence, by adding plant food constituents, the life of the soil will be lengthened and the time until any one of these elements become deficient will be prolonged. Manure improves the physical condition of soils, whether heavy or light. Heavy soils are made less impervious and better aerated and the removal of excessive moisture is facilitated. Light soils are made less open and porous, more retentive of moisture and less subject to losses by leaching. The physical effect of manure on soils is frequently of great importance, and the chemical and bacteriological conditions are influenced indirectly. The evidence of these indirect effects is found in the greater production of available plant food and in the larger crop growth secured because of this fact. Applications of manure influence the bacteriological conditions in the soil directly, however, because of the addition of enormous numbers of bacteria which it contains. These organisms are very largely responsible for the production of available plant food and play an important part in increasing crop yields. The bacteria already present in the soil are stimulated to greater activities thru the addition of manure, and so there is not only a larger number of bacteria, but a very much greater action. There are probably many cases where the bacterial effects of manure are of major importance, especially on soils which are fairly well supplied with organic matter. It may be that the beneficial effect on the Tama silt loam may be due to the bacteriological influence of the material. On most soil types, however, the value of manure is undoubtedly due to a combination of the chemical, physical, and bacterial effects and in the case of the soils of Adair county, the increased crop yields which are commonly secured from the use of manure may be attributed to the improvement in all these conditions and the consequent better production of plant food.

The beneficial effect of manure is shown in the case of general farm crops and no other fertilizing material will prove of as large value if manure is not applied at the same time. When other fertilizers are employed in the county, therefore, they should be used in addition to manure, if economic results are to be secured. This statement applies, of course, only to livestock farming conditions and if manure is not available for use on the farm, some other source of organic matter must be employed.

The large increases secured from the application of manure to soils serve to emphasize the importance of preserving the manure produced on the farm in order to permit of the largest possible effects. If it is exposed in loose piles to the action of the weather and the leaching of rains, 70 to 90 percent of the valuable constituents present may be washed away. When such losses occur, crop growth is not benefited to anything like as large an extent as it should be, hence improper storage of manure may mean actual money losses because of lower crop yields.

There are various ways in which manure may be stored until it can be applied to the soil and no one method can be recommended for use under all farm conditions. It may be stored in a covered yard or pit and protected from the weather, or it may be composted, or some other method may be employed which will keep the manure moist, compact and protected from the weather. The farmers of Adair county should see to it that the manure produced on their farms is returned to the land with as little loss of valuable material as possible, and they may be assured that the results obtained from its application will more than warrant any expense involved in taking proper care of the material. There are some instances where manure may be applied as produced, and, in such cases, there is, of course, no storage problem, but in general the farmer must store the manure for some time before he can apply it to the land. It should be kept in mind that when not subject to extensive losses by leaching and destructive fermentation, manure may return to the land 75 to 80 percent of the plant food constituents which have been removed by the crops grown. Hence there can be no question of the importance of preserving manure with the greatest of care in order to aid in keeping up the fertility of the soils, as well as to aid in increasing crop yields.

On the average livestock farm the production of manure is unfortunately insufficient to permit of any large application to all of the soils of the farm. The usual application amounts to 8 or 10 tons per acre once in a four-year rotation. Larger applications than this may sometimes be made with profit on very light textured types and especially for truck and garden crops, but for general farm crops it is usually not desirable to apply more than 16 to 20 tons per acre, and on most farms such applications are not possible because of the small amount of manure produced. It should be remembered that if very large applications are made to one field, the remainder of the soils of the farm may suffer for a lack of organic matter and it is much more desirable to apply manure at regular intervals and in reasonable amounts to all the soils of the farm in order to keep up crop yields and keep the soils in the best condition of fertility. On the average livestock farm, there is hardly sufficient manure to maintain the supply of organic matter and nitrogen and hence some other material must be utilized to supplement the farm manure if the supply of these constituents is to be kept up. On the grain farm, some other materials must be employed as substitutes for farm manure. Under both systems of farming, therefore, there are cases where green manuring should be practiced. This involves a turning under of some green crop in the soil and, when properly practiced, may lead to considerable improvement in the soil conditions.

Leguminous crops are the most desirable for use as green manures, owing to the fact that when well inoculated they utilize the nitrogen of the atmosphere and fix it in the soil, where it serves to supply food for subsequent crops. Non-legumes may be equally valuable from the standpoint of supplying organic matter, but they do not aid in maintaining the nitrogen supply in the soil. Leguminous crops may be considered as nitrogenous fertilizers as well as sources of organic matter. When the organic matter in soils is low, the nitrogen content is usually low, also, and hence there are very few instances where legumes would not be more desirable than non-legumes for use as green manures. There are many legumes which may be grown under a wide variety of conditions and hence some one may be chosen which will fit in with almost any rotation.

There are undoubtedly cases in Adair county where green manuring may be practiced profitably, particularly where the soils are not very well supplied with organic matter and farm manure is not available for use in any considerable amounts. Green manuring is not a practice, however, which can be followed successfully under all conditions and it is very important that care be used in following this method of improving soil conditions. A heavy crop should not be turned under in the soil when it is dry, as there may be an injurious effect because of interference with the moisture conditions. In some cases it would undoubtedly be more desirable to plow under only a portion of the crop, rather than the entire amount, in order to secure the best results. The time of plowing under is important, as is also the depth of plowing. There are other points of importance in connection with green manuring which can only be considered in connection with individual soil conditions. The Soils Section will advise regarding green manuring under special soil conditions, upon request.

The utilization of all crop residues, such as straw and stover, is also important to aid in keeping up the organic matter content in soil. If they are burned or otherwise destroyed, as is often the case, there is an actual waste of valuable material. Not only do they supply organic matter to the soil, but they also return some of the plant food constituents which have been removed in the crops grown and thus lengthen the life of the soil. On the livestock farm, crop residues may be used for feed or bedding and returned to the soil with the manure. On the grain farm they may be stored, allowed to become partially decomposed before application, or they may be applied directly to the soil. These materials are of particular value on the grain farm, owing to the lack of manure, but they should be used just as carefully on the livestock farm in order to supplement the manure. Frequently these materials have distinctly beneficial effects on crop growth and it is very important under all systems of farming that they be properly utilized if the fertility of the soil is to be economically and permanently maintained.

THE USE OF COMMERCIAL FERTILIZERS

The analyses of the soils of Adair county have shown that the phosphorus supply is rather low in practically all cases. In fact, it seems evident that phosphorus fertilizers will need to be applied to these soils in the near future if crop production is to be kept satisfactory. Furthermore, the amount present is so low that it would seem probable that these materials could be used with profit in some cases at the present time. The total supply of phosphorus or of any other element in soils does not indicate definitely whether or not crops will be properly supplied with the particular constituent, inasmuch as crop growth is determined by the amount of available plant food rather than by the total store which is present. There is no relation between the amount of available plant food in soils and the total supply, and there is no satisfactory method of determining the amount of available phosphorus present under any particular conditions, except to apply a phosphorus fertilizer and determine whether or not it increases crop yields. But where the supply of an element is very low, it is reasonably certain that there will be an insufficient amount of that element changed into an available form.

The greenhouse experiments on the soils from Adair county indicate that phosphorus fertilizers may be of value on some of the soils of the county at the present time, and the results of the field experiment in another county on the same soil type confirms this indication. These results cannot be considered conclusive, inasmuch as the greenhouse tests should be confirmed by results of experiments on the same soils in Adair county, but they certainly indicate the results which may be expected on the soils of the county in general. It is very desirable that tests of phosphorus fertilizers be made under individual farm conditions in order to determine whether or not these materials may be used with profit at the present time.

If phosphorus is needed on soils, it may be applied either in the acid phosphate or the rock phosphate form. Acid phosphate contains the element in an available form, but it is considerably more expensive than rock phosphate. Rock phosphate, on the other hand, has a low rate of availability and considerably larger applications must be made. It is, however, a much cheaper material. In order to determine which of these phosphorus carriers should be used, the relative value of the crop increases secured must be determined and compared with the actual cost of the materials supplied. Rock phosphate is applied but once in a rotation, while acid phosphate is added annually. Rock phosphate does not give its largest effects the first year it is applied, and hence it is important that comparative tests of these two materials be carried on over a period of at least a four-year rotation before conclusions are drawn. The field experiments in Adair county include tests of these two materials and eventually they will show not only the need of phosphorus, but which material should be employed. The results of these field tests will be published in a later supplementary report. At present, farmers may determine the need of phosphorus and select the most desirable material by carrying out tests of rock and acid phosphate under their individual conditions. Such tests may be planned and carried out on practically any farm and with little difficulty. Directions which may be followed for testing these materials are given in circular 51 of the Iowa Agricultural Experiment Station. If profit is shown from the use of any of the materials tested, on small areas, then the same material may be applied to a large area with assurance of value. The farmers in Adair county who are interested in securing larger crops and making their soils more productive are urged to determine the value of phosphorus fertilizers under their own soil and farm conditions.

There is no large supply of nitrogen in any of the soils in Adair county and in some instances the amount of this element is undoubtedly rather low for satisfactory crop growth. It is evident that some means must be employed to keep up the supply of nitrogen in soils and in some cases efforts should be made to increase the total supply of this element. Nitrogen is removed from soils continually by cropping and by drainage and consequently there may be a very rapid decrease in the supply of this element. It is essential, therefore, that some nitrogenous fertilizer be used on the soils of the county.

The proper preservation and application of farm manure will return a large part of the nitrogen taken out of the soils by the crops grown, so that this material may be considered a very important nitrogenous fertilizer and, when it can be applied in considerable amounts, the use of other nitrogenous fertilizers may not be necessary. It is a much simpler matter, therefore, to keep up the nitrogen supply in the soil on the livestock farm, but even where farm manure is produced and utilized under average livestock farming conditions, there is not sufficient to provide for all the soils of the farm. On the grain farm some other sources of nitrogen must be sought. Under both systems of farming the use of leguminous crops as green manures provides the cheapest and most efficient nitrogenous fertilizer. Rotations should always contain a legume and if the legume is inoculated and the crop is properly handled, there may be an addition of nitrogen to the soil, owing to the ability of the legume to take up nitrogen from the atmosphere. Under average soil conditions only a portion of the nitrogen in the legume is taken from the air, the remainder coming from the soil, and if a part of the legume crop is removed from the land, there will generally be no addition of nitrogen thru the growth of the crop and may be an actual reduction in the total supply. In order to serve as a nitrogenous fertilizer, therefore, the legume should be utilized either in whole or in part as a green manure crop. If the seed only of the legume is removed and the remainder of the crop is turned under in the soil, there may be a distinctly beneficial effect on the nitrogen as well as on the organic matter supply. Legumes may also be employed in the rotation as catch crops and thus serve as nitrogenous fertilizers, supplying also valuable amounts of organic matter.

The proper use of all crop residues on the farm will aid materially in keeping up their nitrogen supply, because of the actual return of the nitrogen removed from the soils by crops grown. Farm manure, crop residues and leguminous green manures are much more desirable and less expensive than commercial nitrogenous fertilizers. The latter materials cannot be recommended for general use at the present time. They may be employed in small amounts as top-dressings to stimulate the early growth of some crops, but for general farm crops the use of inoculated legumes is much more satisfactory and profitable. If the commercial materials prove of value on small areas, however, they may be used without fear of injuring the soil.

Tests of many of the soils of the state which were carried out a few years ago showed a large amount of potassium in all cases, and there is no doubt but that the soils of Adair county are in general well supplied with this constituent. If it is made available sufficiently rapidly, as it usually is where the soils are kept in the best physical and chemical condition for bacterial action, there is enough to provide for satisfactory crops almost indefinitely. It would hardly seem likely, therefore, that potassium fertilizers could be used with profit in any case at the present time for the growth of general farm crops. Such materials may be employed in small amounts as top-dressings to aid the early growth of some plants, but on the average farm they would probably not prove profitable. There is no objection to the use of these materials, however, if they are tested on small areas and yield profitable returns, as they would have no injurious effects on the soil. It is very important that the soils be well drained and thoroly cultivated and that the supply of organic matter be adequate. Under such conditions, potassium will be produced sufficiently rapidly in an available form from the store already present in the soil and crops will secure all of this element that they need.

Complete commercial fertilizers contain the three essential elements, nitrogen, phosphorus, and potassium, and they usually supply these elements in an available form. It might seem, therefore, that these materials would prove of value under many farming conditions. It is believed, however, that nitrogen can be supplied more economically in the form of leguminous green manures and potassium is hardly likely to be lacking. Hence it would seem that phosphorus fertilizers might prove more profitable. Experimental work now under way includes the testing of a complete fertilizer in comparison with rock phosphate and acid phosphate. The indications from these experiments thus far are that for general farm crops the phosphorus carriers are more desirable, owing to the fact that the complete brands are more expensive. Very large crop increases would need to be secured to make the complete brands profitable and very much larger yields than those secured by the use of acid phosphate would be required to warrant the application of the complete brand in preference to the phosphate. Eventually it is hoped that definite conclusions may be drawn regarding the comparative value of all these materials. For the present, the complete brands cannot be recommended for general use in Adair county. Farmers who are interested in any particular material may test it on a small area, compare it with a phosphorus fertilizer and, if profitable crop increases are secured, an increase which is more profitable than that produced by the phosphate, then the particular brand may be employed with the assurance of profit. There is no objection to the use of complete commercial fertilizers and they do not injure the soil. They should not be employed, however, unless they are proved to be profitable.

DRAINAGE

The soils of Adair county are generally adequately drained, but there are areas in several of the types where the installation of tile would improve soil conditions and permit of greater crop growth. The Grundy silt loam occurs on more or less level areas and the subsoil is rather impervious and, in many cases, drainage is not adequate. Small areas in the Tama silt loam where the topography is more level have been benefited by the installation of tile. There are also areas in the Shelby loam where moisture conditions are not satisfactory for the best crop growth. Occasionally in the Judson silt loam, tiling might be of value. The Wabash loam and Wabash clay loam of the bottomlands are imperfectly drained and are also subject to overflow.

Wherever moisture conditions are not satisfactory, the installation of tile would prove of value from the standpoint of increased crop production. No other soil treatment will prove of value if the soil is poorly drained. The first treatment needed to insure satisfactory crop growth is to take care of the removal of excess moisture. The installation of tile may be rather expensive, but the results secured in the way of increased crop yields will more than warrant the expense. In general it may be said that while the soils of Adair county are fairly well drained, there are some instances where tiling would prove of value and the farmers of the county should see to it that they are not limiting their crop yields because of unsatisfactory moisture conditions which might be remedied by laying a line of tile.

THE ROTATION OF CROPS

The continuous growing of any one crop very rapidly reduces the fertility of the soil and so is a very undesirable practice. Furthermore, continuous cropping is not a profitable practice, even if the particular crop is of considerable value. Less income from the land will be secured over a period of years than where a rotation has been employed. This is due to the fact that crop yields under a system of continuous cropping are very rapidly decreased, while under a rotation good yields may be maintained, or even increased, and even tho less valuable crops are included, the returns from the soil will be greater. No specific rotation experiments were carried out in Adair county, but several rotations may be suggested which have proved satisfactory thruout the state, and from among these, some one may be chosen as suitable for use in this county. These rotations may be modified as seems desirable and, in fact, almost any rotation may be employed, provided it contains a legume and a money crop.

I. FOUR OR FIVE-YEAR ROTATION

First Year —Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation.)
Second Year—Corn.
Third Year —Oats (with clover or with clover and timothy.)
Fourth Year—Clover. (If timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy.)

II. FOUR-YEAR ROTATION WITH ALFALFA

First Year —Corn.
Second Year—Oats.
Third Year —Clover.
Fourth Year—Wheat.
Fifth Year —Alfalfa. (This crop may remain on the land five years. This field should then be used for the four-year rotation outlined above.)

III. THREE-YEAR ROTATION

First Year —Corn.
Second Year—Oats or wheat (with clover seeded in the grain.)
Third Year —Clover. (Only the grain and clover seed should be sold; in grain farming most of the crop residues, such as corn, stover, and straw should be plowed under. The clover may be clipped and left on the land to be returned to the soil.)

THE PREVENTION OF EROSION

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur; hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, the rain falling on it will, of course, wash over it, and much of the soil may be carried away in this manner, to the detriment of the land.

Light, open soils which absorb water readily are not apt to be subject to erosion, while heavy soils such as loams, silt loams and clays, may suffer much from heavy or long-continued rain. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion, while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action.

The careless management of land is quite generally the cause of the erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or, if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and the absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manure, green manures and crop residues, if soil subject to erosion is to be properly protected. By the use of such materials, the absorbing power of the soil is increased, and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. With all these treatments, the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and the crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance, but is less harmful and is

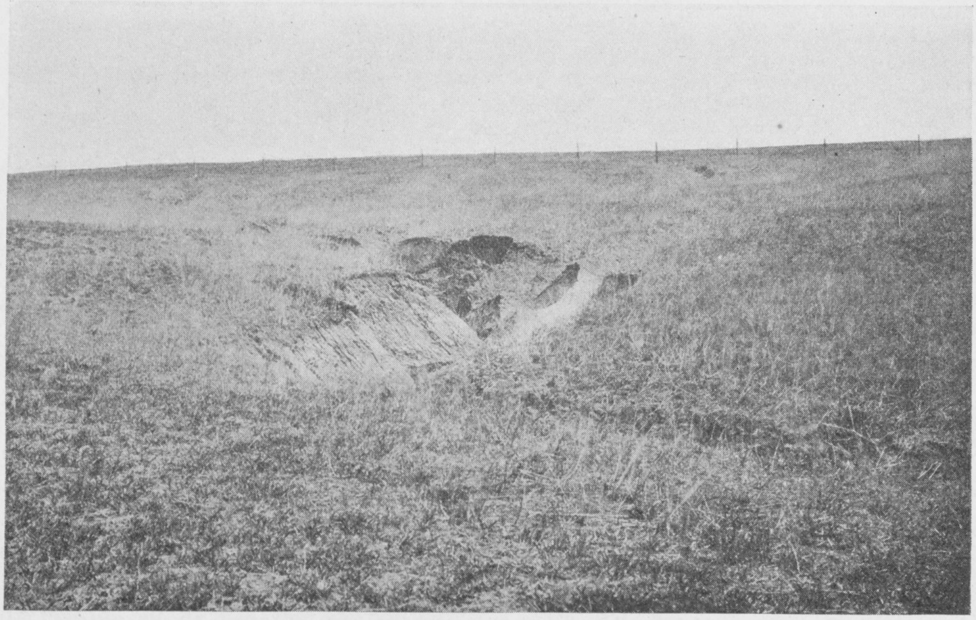


Fig. 8. Erosion is a serious problem over much of the Shelby loam area.

usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked, an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is more costly and inconvenient.

Erosion occurs to a considerable extent in several of the soils of Adair county, the Shelby loam, Lindley loam and Clinton silt loam being particularly subject to this injurious action. The Tama silt loam is also affected to a considerable extent and, in fact, the shallow phase of this type is a result of extensive erosive action. It is very important that some means be taken to protect all these soils from the injurious effect of erosion and from among the methods suggested here, one may be chosen which will serve under almost any condition. There are probably some cases where the soil should preferably be left in pasture if extensive washing is not to occur. The means which may be employed to control or prevent erosion in Iowa may be considered under five headings, as applicable to "dead furrows," to small gullies, to large gullies, to bottoms and to hillside erosion.

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope or at a considerable angle to it, frequently result in the formation of gullies.

"Plowing In." It is quite customary to "plow in" the small gullies that result from these dead furrows and, in level areas where the soil is deep, this "plowing in" process may be quite effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In." The method of "staking in" is better, as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point upstream. Additional brush may also be placed above the stakes, with the tops pointing upstream, permitting the water to filter thru, but holding the fine soil.

Earth Dams. Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

SMALL GULLIES

Gullies result from the enlargement of surface drainageways and may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways, but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

Checking Overfalls. The formation of small gullies or ditches is practically always the result of overfalls, and one of the most important problems is, therefore, the checking of these overfalls and preventing them from working back and extending the size of the gully. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush both are held in place by cross pieces nailed to the posts. This method does not fill the existing ditch, but does prove very satisfactory for preventing the overfall from working back upstream. It is an installation which is most desirable before any success can be had in filling small or large gullies.

"Staking In." The simplest method of controlling small or moderate-sized gullies, and the one that gives the most general satisfaction, is the "staking in" operation recommended for the control of dead furrow gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case consists in using the brush without stakes. The brush is cut so that a heavy branch pointing downward is left near the top. This heavy branch is caught between a fork in the lower part of the brush-pile, or hooked over one of the main stems and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed downstream instead of upstream, which keeps it from being washed away as rapidly by the action of a large volume of water. A series of these brush-piles may be installed up the course of the gully and, with the regular repair of washouts or undercuttings, may prove very effective.

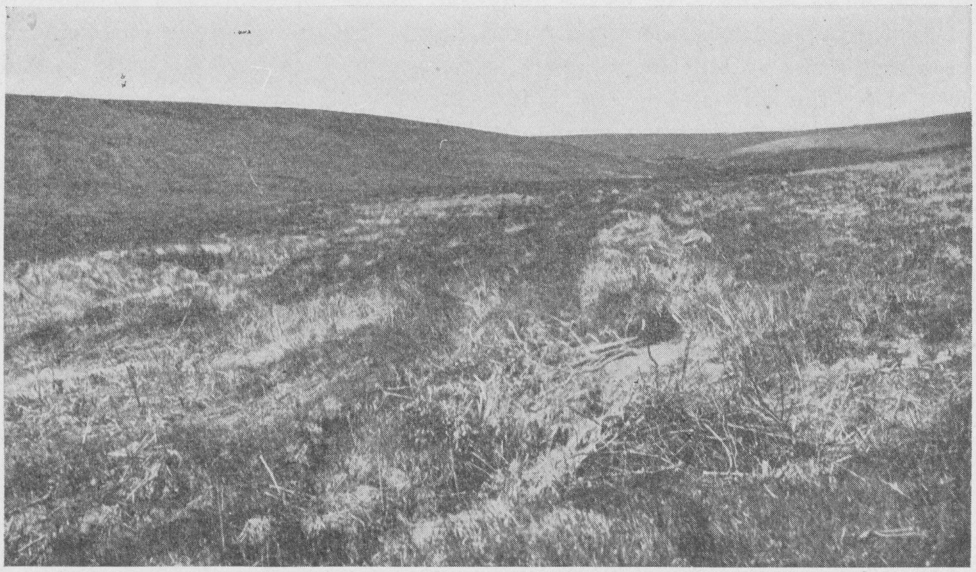


Fig. 9. Stakes across this gully, supplemented by brush and straw, are checking erosion in Shelby loam.

The modification of this system of staking in which is being used with success in some sections, consists in covering the bottom and sides of the ditch with straw for a distance of 4 to 10 feet, depending upon the width of the ditch. Brush ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed upstream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of posts will depend, of course, upon the size of the gully. These posts should be set well into the ground and spaced about 4 feet apart, being arranged in a V-shape with the point downstream and lower in the center than at the sides of the ditch. This modification of the staking in method is proving very satisfactory.

The Straw Dam. A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is long or branching, it should be placed near the middle or below the junction of the branches, or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material, and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving of time, labor and inspection.

The Earth Dam. The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise too large amounts of water may accumulate above the dam and wash it out. In general it may be said that when not provided with a suitable outlet under the dam for surplus water, the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" Dam. This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a "T" being inserted in the tile just above the dam. This "T," called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or runoff, to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully, and higher in the center than at the sides, to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass.

The Adams Dam. This dam is practically the same as the Christopher or Dickey dam. In fact, the principle of construction is identical. In some sections the name "Adams dam" had been applied and hence it is mentioned separately. This is one of the most satisfactory methods of filling gullies, and the dam may also serve as a bridge. The installation of a culvert is generally made of sewer tile with tightly cemented joints, and it is recommended that the inlet to the tile be protected from clogging by the installation of posts supporting woven wire. The concrete or plank spill platform is a very important feature of the Adams dam and it is also recommended that an upstream concrete guard be constructed so that the face of the dam is protected. Taking into account the cost, maintenance, permanence and efficiency, the Adams dam or the Christopher or Dickey dam may be considered as the most satisfactory for filling ditches and gullies, especially the larger gullies.

The Stone or Rubble Dam. Where stones abound, they are frequently used in constructing dams for the control of erosion. With proper care in making such dams the results in small gullies may be quite satisfactory, especially when openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

The Rubbish Dam. The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish, even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, in the same way as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The Woven Wire Dam. The use of woven-wire, especially in connection with brush or rubbish, has sometimes proved satisfactory for the prevention of erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" system. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

Sod Strips. The use of narrow strips of sod along natural surface drainage-ways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small, as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and, for quick results, sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and might be employed to advantage in many other cases.

The Concrete Dam. One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. This dam is, however, rather expensive. Then too, it may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to the high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage. The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to the depth of the tile increases the water-absorbing power of the soil, and thus decreases the tendency toward erosion. Catch wells properly located over the surface, and consisting of depressions or holes filled with coarse gravel and connected with the tile, help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES

The erosion in large gullies, which are often called ravines, may generally be controlled by the same methods as in the case of small gullies. The Christopher or Adams dam, already described, is especially applicable in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

Erosion frequently occurs in bottomlands and, especially where such low-lying areas are crossed by small streams, the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and Tiling. The straightening of the larger streams in bottomland areas may be accomplished in any community and, while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottomland and it often proves very efficient.

Trees. Erosion is sometimes controlled by rows of such trees as willows, which extend up the drainage channels. While the method has some good features, it is not generally desirable. The rows of trees often extend much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity, because of their shade and because of the water which they remove from the soil. In general, it may be said that in pastures, bottomlands and gulches, the presence of trees may be effective in controlling erosion, but a row of trees across cultivated land or even extending out into it, cannot be recommended.

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Use of Organic Matter. Organic matter or humus is the most effective means of increasing the absorbing power of the soil, and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose, or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues, such as straw and corn stalks, may also be turned under in soils to increase their organic matter content. In general it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

Growing Crops. The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also desirable for use in such locations. The root system of such crops as these holds the soil together and the washing action of rainfall is reduced to a marked extent.

Contour Discing. Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and has proved quite satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring, preparatory to seeding small grain, and also on fall-plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first, as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

Sod Strips. The use of narrow strips of sod is very desirable for preventing hillside erosion, as well as for the preventing of gully formation. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil.

Deep Plowing. Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall, as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation, as too much subsoil may be mixed with the surface soil and the productive power of the soil may therefore be reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value, both in increasing the feeding zone of plant roots and in making the soil more absorptive and therefore less subject to erosion.

INDIVIDUAL SOIL TYPES IN ADAIR COUNTY*

There are eight individual soil types in Adair county and these, together with the shallow phase of the Tama silt loam, make nine soil areas in the county. These are divided into four large groups, according to their origin and location, known as drift soils, loess soils, terrace soils, and swamp and bottomland soils.

DRIFT SOILS

There are two drift soils in the county, classified in the Shelby and Lindley series. Together they cover 37.9 percent of the total area.

SHELBY LOAM (79)

The Shelby loam is the largest drift soil in the county and the second largest soil type, covering 36.4 percent of the total area. It occurs in all parts of the county in considerable areas, the only portion where it is not found extensively being the northeast corner. It occurs on the slopes between the stream bottoms and the areas of upland Tama. Thus it is developed in strips bordering the slopes of valleys and ravines and it also is found in some broader and more continuous tracts near the larger streams.

The surface soil of the Shelby loam is a brown to dark brown loam or gritty silt loam to a depth of 8 to 12 inches. It grades below this point into a loamy

*The descriptions of the individual soil types given in this section of the report very closely follow those given in the Bureau of Soils Report.

sandy clay, brown or yellow in color, mottled with brown, yellow and gray. Below 20 to 24 inches it is somewhat lighter in color and the mottling is more pronounced. In the southeastern part of the county, there is a higher content of sand in the soil than in other parts of the area. The character of the soil material varies considerably, especially where the type joins the Tama silt loam and the shallow phase Tama. Frequently the boundary lines between these types is very difficult to draw. The subsoil of the type frequently contains calcareous material and it also contains black iron concretions.

In topography the Shelby loam varies from sloping and rolling to somewhat hilly. Along the south side of the eastward or westward flowing streams, the areas are steeper and more broken than are areas on the slopes descending from the north. Drainage is generally good, altho in some depressions along small streams there may be narrow swales and seepy places. Some erosion is constantly occurring in the type and gullies are of rather frequent occurrence.

About one-half of the Shelby loam is under cultivation, the remainder being utilized for pasture and hay land. Originally this type was forested, and on the steeper and more broken areas there is still a scrubby growth of white, black and bur oak and some hickory, elm, and hazel brush. In the cultivated areas, corn is the most important crop grown, followed by oats and wheat. Barley, rye, millet, Sudan grass, sorghum and alfalfa are minor crops on this type. Corn yields from 25 to 60 bushels per acre, oats from 40 to 50 bushels, wheat 15 to 25 bushels, and barley 20 to 30 bushels per acre. Timothy and clover produce 1 to 2 tons of hay per acre, the wild grasses giving smaller yields. The type ordinarily supports good pastures, which are largely bluegrass.

Yields of general farm crops may be increased on the Shelby loam thru the proper handling of the soil. It is chiefly in need of organic matter and should receive liberal applications of farm manure on the cultivated portion, if the

Fig. 10. Shelby loam slopes make fine pasture.

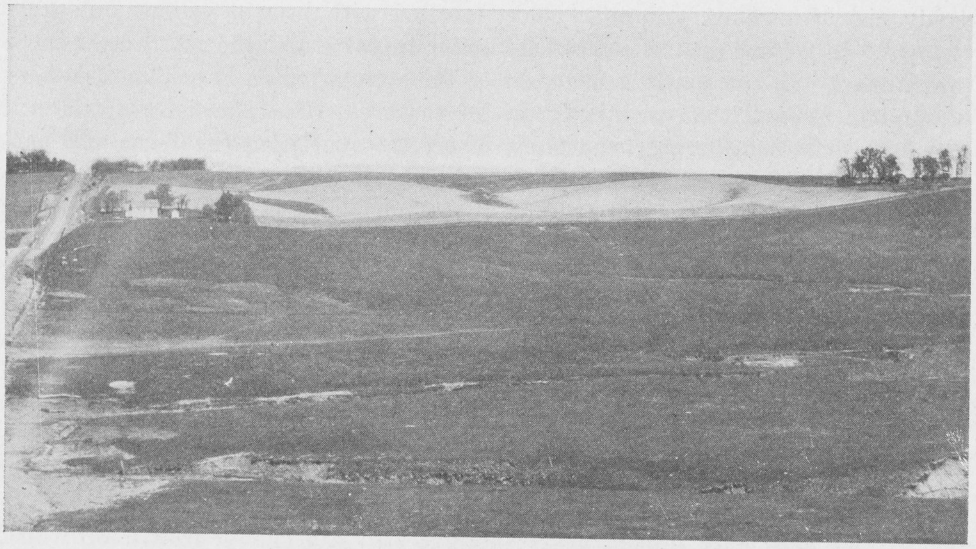


Fig. 11. Shelby loam topography is sloping and rolling, often hilly.

best crop yields are to be secured. The type is usually acid in reaction and the application of lime would prove of value where legumes are to be grown. The small amount of lime occasionally occurring in the subsoil will not appreciably affect the lime requirement of the surface soil. The type is low in phosphorus and applications of phosphorus fertilizers will undoubtedly be needed in the future, if they do not prove of value at the present time. There are indications from field tests and farm experience, however, that phosphorus may prove a profitable fertilizer for use on this soil now. The soil certainly will respond to liberal applications of manure and, if manure is not available in sufficient amounts, leguminous crops should be employed as green manures in order to increase the supply of organic matter and nitrogen. The soil is subject to erosion and the washing away of valuable soil, whether thru gully formation or thru sheet washing, should be prevented by adopting some one of the methods of control suggested earlier in this report. There are undoubtedly some areas of the Shelby which are too rough for the growing of cultivated crops and, in these locations, the type should be left in pasture.

LINDLEY LOAM (65)

The Lindley loam is a minor type in the county, covering only 1.5 percent of the total area. It is, however, the second most extensive drift soil. It occurs mainly in two areas in the county, one along the Middle river in the vicinity of Arbor Hill, and the other along the Middle Nodaway river and the West Fork Nodaway river, west of Avondale Church. Other small areas of the type occur chiefly on the eastern boundary of the county.

The surface soil of the Lindley loam consists of 6 to 7 inches of grayish to yellowish-brown loam or silty loam. Below this point it becomes a friable yellow brown silt loam which, at 24 inches, shows considerable fine and very fine sand and mottlings of gray and rusty brown. Below 30 inches the soil in places is mottled with reddish-brown and is compact and sticky. Gravel occurs thruout the surface soil and subsoil.

In topography the type is rolling to broken and very little of it is suitable for cultivation. Most of the type is used for pasture and much of it is forested, chiefly with oak, hickory, elm and hazel brush. There are a few areas where general farm crops may be grown with success and here the yields are very much the same as on the Shelby loam. In the more rolling areas the soil is cut by small streams and gullies and the surface material is constantly being washed away thru erosion.

The first treatment needed in most cases, if this soil is to be used successfully for cultivated crops, is to prevent the destructive action of rain-water in washing away the surface soil. The addition of organic matter in the form of barnyard manure or leguminous green manures is very important on the cultivated areas in order to cut down erosion to a minimum and also to improve the soil conditions. The soil is acid and in need of lime and if legumes are to be successfully grown this material must be employed. The phosphorus supply is low and phosphorus fertilizers may be of value at the present time and certainly will be needed in the future.

LOESS SOILS

There are three loess types in the county and these, together with the shallow phase Tama, make four loess soil areas. Together they cover over one-half the total area of the county, 51.6 percent. They are classified in the Tama, Clinton and Grundy series.

TAMA SILT LOAM (120)

The Tama silt loam is the largest loess type, and also the largest individual soil type in the county. Together with the shallow phase, it covers 50.4 percent

Fig. 12. About one-half the Shelby loam in Adair county is under cultivation.

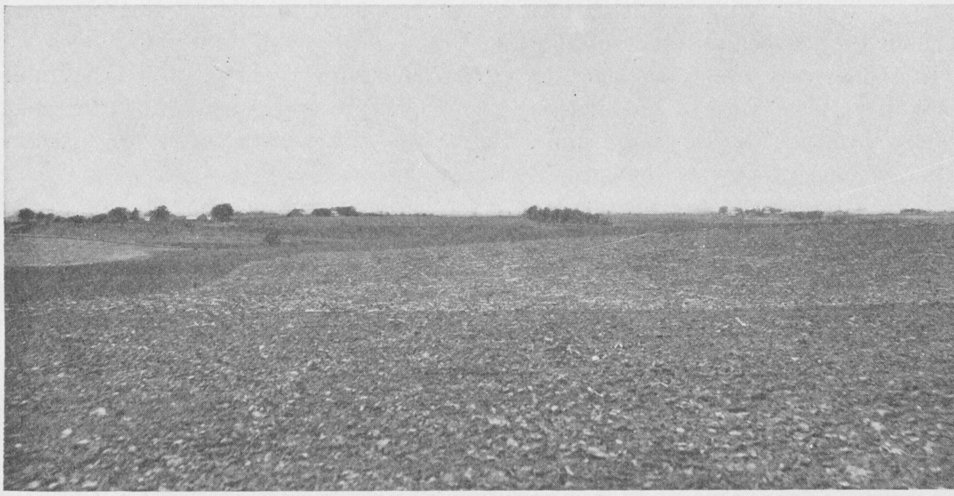


Fig. 13. The Tama silt loam is gently undulating to slightly rolling, and is practically all under cultivation.

of the total area. It occurs in more or less extensive areas in all parts of the county, occupying the more gently undulating to slightly rolling uplands, the area between the various streams and intermittent drainageways. It is usually separated by the more steeply rolling Shelby from the bottomlands along the streams.

The surface soil of the type is a dark brown to nearly black heavy silt loam to silty clay loam, 12 to 20 inches in depth. In the lower part of this surface layer the soil grades into a light brown to light yellowish-brown more compact silt loam or silty clay loam. It becomes somewhat lighter colored at 24 to 30 inches and frequently contains gray, yellow and brown mottlings. In topography the type is nearly level or undulating to gently rolling. The soil is well drained, except in a few shallow depressions at the heads of draws and in a few of the flatter areas.

Practically all of the type is under cultivation and corn, oats, wheat, and barley are the principal crops grown. Corn yields from 30 to 70 bushels per acre, the average yields amounting to 40 to 45 bushels. Oats yield from 40 to 60 bushels per acre, winter wheat from 15 to 30 bushels, spring wheat from 8 to 15 bushels and barley from 20 to 25 bushels per acre. Timothy yields 1 to 1½ tons of hay per acre and other forage crops include sorghum, Sudan grass and alfalfa.

Altho this soil is quite satisfactorily productive, crop yields may be increased thru proper systems of management. The type is acid and in need of lime, if legumes are to be grown successfully. It is not strikingly deficient in organic matter, but applications of manure prove of distinct value and this material should be applied in as large quantities as available. The soil is not very well supplied with phosphorus and phosphorus fertilizers will certainly be needed in the future, if they do not prove of value at the present time. There are indications from some of the experimental work, however, that these materials will yield profitable returns now. Occasionally the type is in need of tiling, but ordinarily the drainage conditions are very satisfactory.

TAMA SILT LOAM (Shallow Phase) (143)

This phase of the Tama silt loam is minor in area, covering about 10 percent of the total area of the county. It occurs in numerous areas, especially around the heads of draws and on slopes along the stream courses, especially the southern slopes. Many of the areas separate the typical Tama of the more level uplands from the rolling to rough Shelby on the slopes to the bottoms. Occasionally it occurs on the areas adjoining the drainage channels and separates the upland soils from the bottomland types.

The surface soil of this phase is a grayish-brown to dark brown silt loam or silty clay loam, 6 to 12 inches in depth. The subsoil is a light brown or dull yellow moderately friable silty clay loam, in many places mottled with gray and brown. In general the lower part of the three foot section is characterized by a lighter color and more pronounced mottlings.

In the extreme southwestern corner of the county there is a variation from the typical phase where the soil is underlaid by a stiff plastic subsoil, light brown in color, mottled with gray, yellow and brown. On the lower parts of slopes the phase may usually be as deep as and have other characteristics similar to the typical silt loam, while up on the slopes, the surface material may be washed away to such an extent that the underlying glacial till is exposed, giving small patches of the Shelby loam. There are certain areas where the mapping of this phase is rather difficult, owing to overlapping with the Shelby loam. The topography of the type is rolling and drainage is usually good. There are a few cases where small depressions and swales lead to unsatisfactory drainage and, in these instances, tiling should be practiced.

This phase of the Tama silt loam is undoubtedly chiefly in need of protection from erosion if crop yields are to be made satisfactory. The phase has been formed mainly from the removal of the surface soil, and the continued washing action will eventually remove all the loessial material and the underlying drift

Fig. 14. A well-graded and dragged highway in the Tama silt loam, Adair county.

formations will appear at the surface. The introduction of organic matter into the soil is of value and, if farm manure is not available for use, it would be very desirable to turn under a legume crop as a green manure. The incorporation of organic matter with the soil is of value because it reduces the injurious washing by rains and also because of the aid which it gives in producing better soil conditions from the more or less infertile subsoil material which is constantly being brought up thru plowing and mixed with the shallow surface material. The type is acid and in need of lime and will undoubtedly respond to applications of phosphorus fertilizers.

CLINTON SILT LOAM (80)

The Clinton silt loam is a minor type in the county, covering 0.7 percent of the total area. It occurs entirely in the eastern part of the county, mostly in the eastern parts of Harrison and Grand River townships, where it joins the areas of the same type in Madison county. It occurs on the ridges and many of the slopes, altho it is occasionally associated with the Lindley and Shelby types.

The surface soil of the Clinton silt loam is a dark grayish-brown friable silt loam about 8 inches in depth. Below this point it becomes a compact, tho friable, light brown silty clay loam, which becomes somewhat lighter in color and less friable in structure at 24 to 28 inches. Mottlings of brown and gray occur and there are also black concretions present.

In topography the type is undulating to rolling, with a few sharply rolling areas. Drainage is well established. Most of the type is in farm land, but some of the more rolling areas are still in forest. The tree growth present includes oak, hickory, elm and box elder.

In the cultivated portions the crops grown are much the same as on the Tama silt loam. The yields, however, are somewhat smaller. The soil is particularly in need of applications of farm manure or the use of leguminous green manures to make it more productive. When cultivated, it should be protected from erosion thru special methods of treatment. It is acid and in need of lime. It is low in phosphorus and for general farm crops, phosphorus fertilizers could probably be used with value.

GRUNDY SILT LOAM (64)

This is a minor type in the county, covering 0.5 percent of the total area. It occurs mainly in the northeastern corner of the county, southeast and east of Stuart. There are small areas, also, in the south central part of the county, near Orient. It is found in irregular-shaped areas on flat ridge tops surrounded by the Tama silt loam.

The surface soil of this type is a dark brown or nearly black friable silt loam, resting on a more compact silty loam, which at 20 to 24 inches changes into a drab rather plastic clay loam, more or less mottled with gray and dull brown. At 28 to 30 inches the subsoil is a compact plastic silty clay, mottled with bright yellow, drab and rusty brown.

In topography the soil is nearly level and owing to this fact and to the impervious subsoil condition, drainage is poor. The installation of tile is the first treatment needed to make this soil satisfactorily productive. Applications of farm manure would be of value. The soil is acid and in need of lime. It is not very well supplied with phosphorus and a phosphorus fertilizer might be used with value at the present time. It certainly will be needed in the future.

TERRACE SOIL

There is one terrace type in the county, classified in the Judson series. It covers only a small portion of the total area, 0.5 percent.

JUDSON SILT LOAM (131)

This type occurs mainly along Middle river in numerous small areas, the largest of which are found in the vicinity of Arbor Hill. A few small areas are found in the western part of the county along the Middle Nodaway river and West Fork Nodaway.

The surface soil of the Judson silt loam consists of a dark brown to dark grayish-brown silt loam, 10 to 14 inches in depth. Below this point the soil becomes a somewhat heavier, but friable, silt loam or silty clay loam, light brown in color, and at 22 to 24 inches this becomes more compact. In many of the depressions and lower lying areas, mottlings of gray and brown are found in the lower part of the 3-foot section. In a few of the smaller areas the surface soil is somewhat lighter than typical, ranging from a light brown to a grayish-brown. In topography, the soil is nearly level or very slightly undulating. Except in a few depressed areas, drainage is good. In only a few instances would tiling be necessary.

Practically all of the type is utilized for cultivated crops, only a few small areas being handled, along with the Wabash soils of the bottom, in permanent pasture. The yields of general farm crops are quite satisfactory, but may be increased thru proper soil treatment. Manure may be applied with value. The soil is acid and should be limed. Phosphorus fertilizers might be used to advantage in some cases.

SWAMP AND BOTTOMLAND SOILS

There are two swamp and bottomland soils in the county, both belonging in the Wabash series. Together they cover 10.0 percent of the total area.

WABASH LOAM (49)

The Wabash loam is the larger of the two bottomland soils, covering 8.4 percent of the total area of the county. It occurs in all parts of the county, bordering nearly all of the smaller streams and most of the larger ones. The most extensive areas of the type are found along the Middle Nodaway river and the West Fork Nodaway.

The surface soil of the type is a dark brown friable loam, 8 to 12 inches in depth. Below this point the subsoil is a grayish-black, dark slate colored, or nearly black heavy loam to silty clay loam. In many places faint mottlings of brown are found at 24 to 30 inches. In some of the narrower areas there are variations, both in color and texture, from the typical Wabash loam, and in these areas there may be a grayish-brown gritty loam or heavy sandy loam

Fig. 15. Pasture on Wabash loam in the bottoms, with Shelby loam in the background.

which, at a depth of 4 to 12 inches, rests on a dark brown to black loam or silt loam. The soil near the stream channels is generally lighter in texture than that further back. Pockets or layers of sandy material may be found in any part of the 3-foot section. The upper subsoil is frequently a dense plastic clay.

In topography the Wabash loam is level and slightly sloping. Here and there it may slope gradually toward the uplands and have some covering of colluvial material, especially in the narrower valleys. The drainage of the type, as a rule, is good, but there are areas where the removal of excessive moisture would be very desirable. Most of the type is subject to overflow regularly and if used for cultivated crops, would need to be protected from flood waters.

The larger part of the type is used for pasture land. Some areas, especially along the stream channels, are timbered with elm, willow, cottonwood, walnut and some oak. Where well drained and protected from overflow, corn and other general farm crops may be grown successfully. Corn yields 20 to 70 bushels per acre and average yields are around 40 to 50 bushels. Oats yield from 30 to 40 bushels and wheat 15 to 25 bushels per acre. Red clover is produced on well drained areas, white clover and bluegrass do well on the more poorly drained areas. Some wild grasses are cut for hay, yielding ½ to 1 or more tons per acre.

This type is mainly in need of protection from overflow and adequate drainage, if cultivated crops are to be grown successfully. Small applications of farm manure would be of particular value when the soil is newly drained. The type is acid and in need of lime. Phosphorus fertilizers will be needed in the future, if they do not prove of value at the present time.

WABASH CLAY LOAM (63)

This is a minor type in the county, covering 1.6 percent of the total area. It occurs mainly in the southwestern part of the county, along the West Fork

Nodaway river. Small areas are found in the northeastern part of the county around Plunger Run and North river.

The surface soil of this type is a dark brown to black clay or silty clay loam, 8 to 10 inches in depth. The subsoil is a nearly black compact clay to silty clay. There is usually very little change in the subsoil conditions to a depth of 3 feet, but sometimes at 24 to 30 inches, the soil may become somewhat lighter and mottlings of brown or yellowish-brown may appear. When wet, the surface soil is sticky and, when dry, it becomes hard and cracks. Small areas where the soil is particularly stiff are known locally as "gumbo" and in such areas the handling of the soil, if cultivated, is of special importance. In topography, the type is nearly level and in many of the areas, drainage is fairly well established. In the lower lying portions, however, drainage is inadequate. The type is subject to overflow.

Most of the soil is utilized as pasture land and affords good grazing. On the cultivated portion, corn is the chief crop grown and yields are very much the same as on the Wabash loam. The type is in need of drainage and protection from overflow, if it is to be brought under cultivation. It will respond to small applications of farm manure. It is acid and should be limed and phosphorus fertilizers will probably prove of value.

APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil tyes, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in co-operation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main soil types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and insure the best crop production.

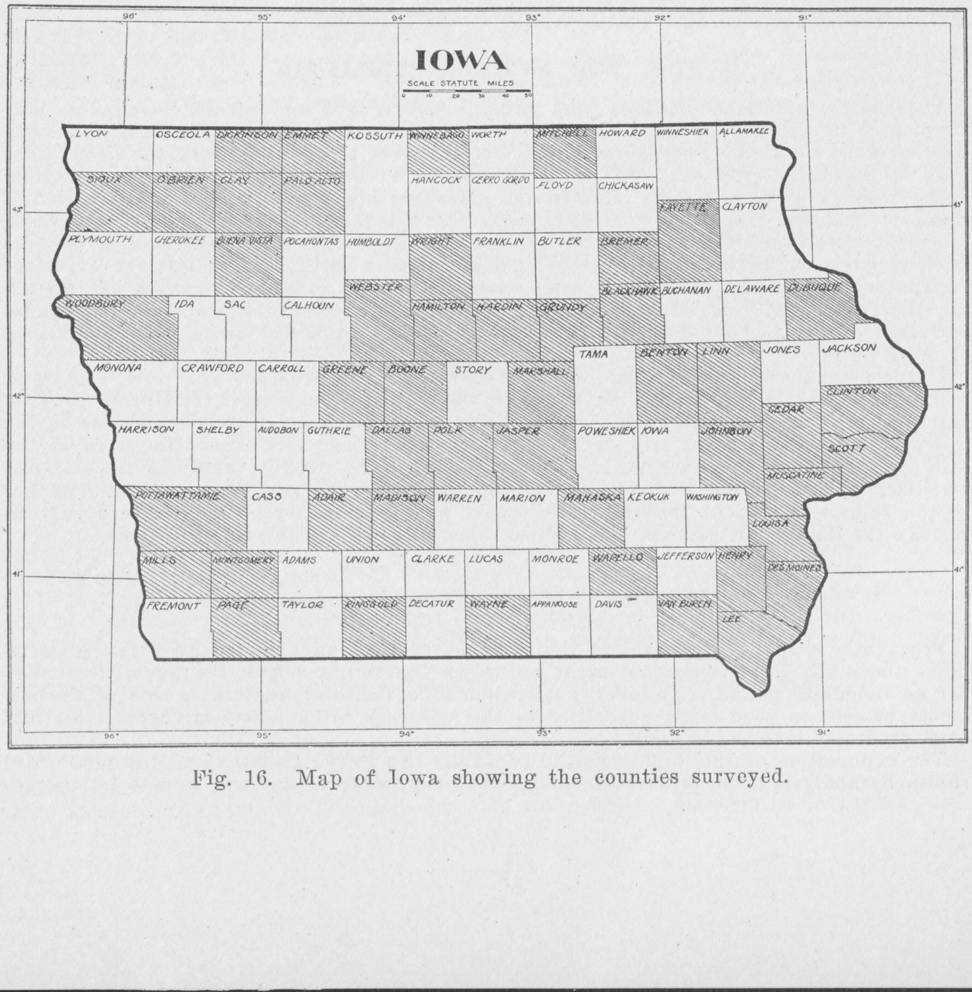


Fig. 16. Map of Iowa showing the counties surveyed.

The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year being determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions signed by the residents, and especially by the farmers or farmers' organizations of the county, should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

The reports giving complete results of the surveys and soil studies in the various counties will be published in a special series of bulletins as rapidly as the work is completed. Some general information regarding the principles of permanent soil fertility and the character, needs and treatment of Iowa soils, gathered from various published and unpublished data accummulated in less specific experimental work will be included in or appended to all the reports.

PLANT FOOD IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced", as in market gardening, some nitrogenous fertilizer may be of value.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil-derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the soil. For example, if potassium is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such an abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, application of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavail-*

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO_3$)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potass'm	Nit'g'n	Phosphorus	Potass'm	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	......	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	......	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	......	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	......	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	......	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay	3 T.	120	15	90	19.20	1.80	5.40	16.40

able. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

Phosphorus is found in soil mainly in the mineral known as apatite and in other insoluble substances. Potassium occurs chiefly in the insoluble feldspars. Therefore, both of these elements, as they normally occur in soils, are unavailable. However, the growth of bacteria and molds in the soil brings about a production of carbon dioxide and organic acids which act on the insoluble phosphates and potassium compounds and make them available for plant food.

Calcium occurs in the soil mainly in an unavailable form, but the compounds containing it are attacked by the soil water carrying the carbon dioxide produced by bacteria and molds and as a result a soluble compound is formed. The losses of lime from soils are largely the result of the leaching of this soluble compound.

Sulfur, like nitrogen, is present in soils chiefly in plant and animal remains, in which form it is useless to plants. As these materials decompose, however, so-called sulfur bacteria appear and bring about the formation of soluble and available sulfates.

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished, care should always be taken that the soil is in the best condition for the growth of bacteria.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, altho there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the element in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growth of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

Of course, if the crops produced are fed on the farm and the manure is carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food loss.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

This loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported,* revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large, there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still

*Bulletin 150, Iowa Agricultural Experiment Station.

present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for soil production, largely because they help to control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for a lack of the water necessary to bring them their food and also for a lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

The loss of moisture by evaporation from soils during periods of drouth may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holding power of light soils.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotation. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be hindered or stopped and crops may suffer. The use of legumes in rotations is of particular value since when they are well inoculated and turned under, they not only supply organic matter to the soil, but they also increase the nitrogen content.

There is a third explanation of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the same crop, but have no effect on certain other crops. In a proper rotation the time between two different crops of the same plant is long enough to allow the "toxic" substance to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

But, whatever the reason for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that rotations should always contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the use of legumes, either as regular or "catch" crops in the rotation.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

Farm manure is composed of the solid and liquid excreta of animals, litter, unconsumed food and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply large enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best methods of treatment and storage, 15 percent of its valuable constituents, mainly nitrogen, are lost. Furthermore, only in a very few instances is enough produced on a farm to supply its needs. On practically all soils, therefore, some other material must be applied with the manure to maintain fertility.

Crop residues, consisting of straw, stover, roots and stubble, are important in keeping up the humus, or organic matter content of soils. Table I shows that a considerable portion of the plant food removed by crops is contained in the straw and stover. On all farms, therefore, and especially on grain farms, the crop residues should be returned to the soil to reduce the losses of plant food and also to aid in maintaining the humus content. These materials alone are, of course, insufficient and farm manure must be used when possible, and green manures also.

Green manuring should be followed to supplement the use of farm manures and crop residues. In grain farming, where little or no manure is produced, the turning under of leguminous crops for green manures must be relied upon as the best means of adding humus and nitrogen to the soil, but in all other systems of farming also it has an important place. A large number of legumes will serve as green manure crops and it is possible to introduce some such crop into almost any rotation without interfering with the regular crop. It is this peculiarity of legumes, together with their ability to use the nitrogen of the atmosphere when well inoculated and thus increase the nitrogen content of the soil, which gives them their great value as green manure crops.

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated, or by the use of inoculating materials that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is impossible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. Experiments are now under way to show which is more economical for all farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and acid phosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the tests of many representative soils reported in bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 17.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

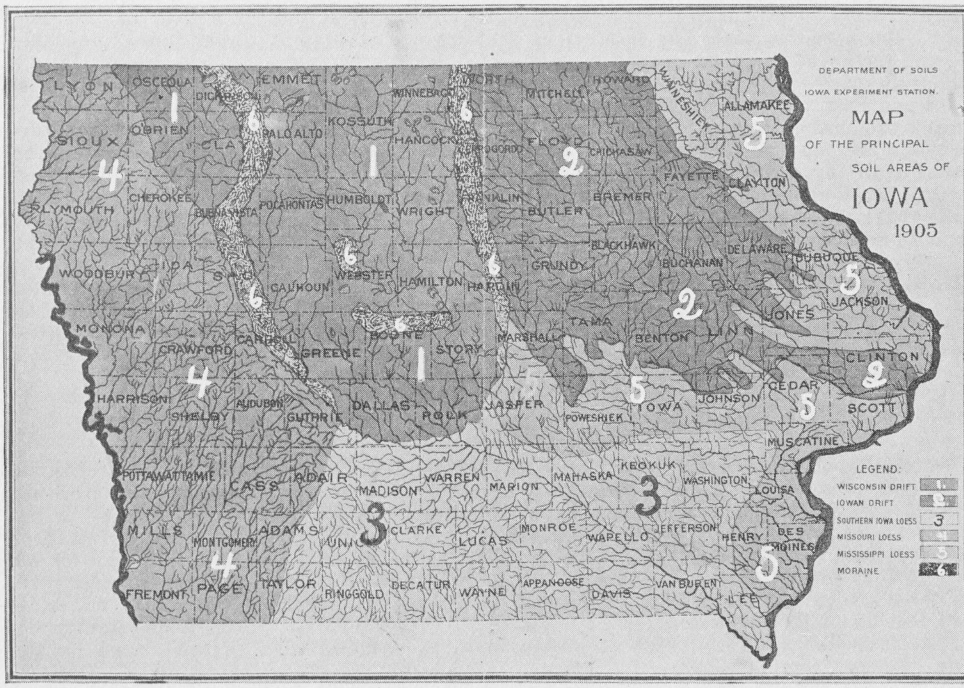


Fig. 17. Map showing the principal soil areas in Iowa

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thoro and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into the soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Agricultural Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.

2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter	All partially destroyed or undecomposed vegetable and animal material.
Inorganic matter	Stones—over 32 mm.* Gravel—32—2.0 mm. Very coarse sand—2.0—1.0 mm. Coarse sand—1.0—0.5 mm. Medium sand—0.5—0.25 mm. Fine sand—0.25—0.10 mm. Very fine sand—0.10—0.05 mm. Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.‡

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

*25 mm. equals 1 in. †Bureau of Soils Field Book. ‡Loc. cit.

The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection by and consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.